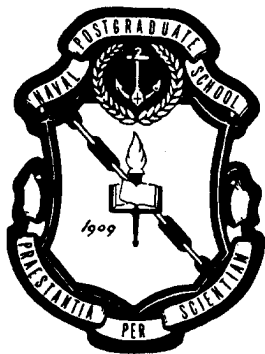NPS-09-98-006

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Monterey, California 93943-5138

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OF
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1997

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Superintendent   Provost

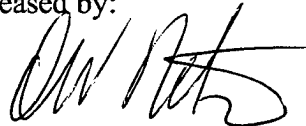This report was prepared for the Naval Postgraduate School, Monterey, CA.

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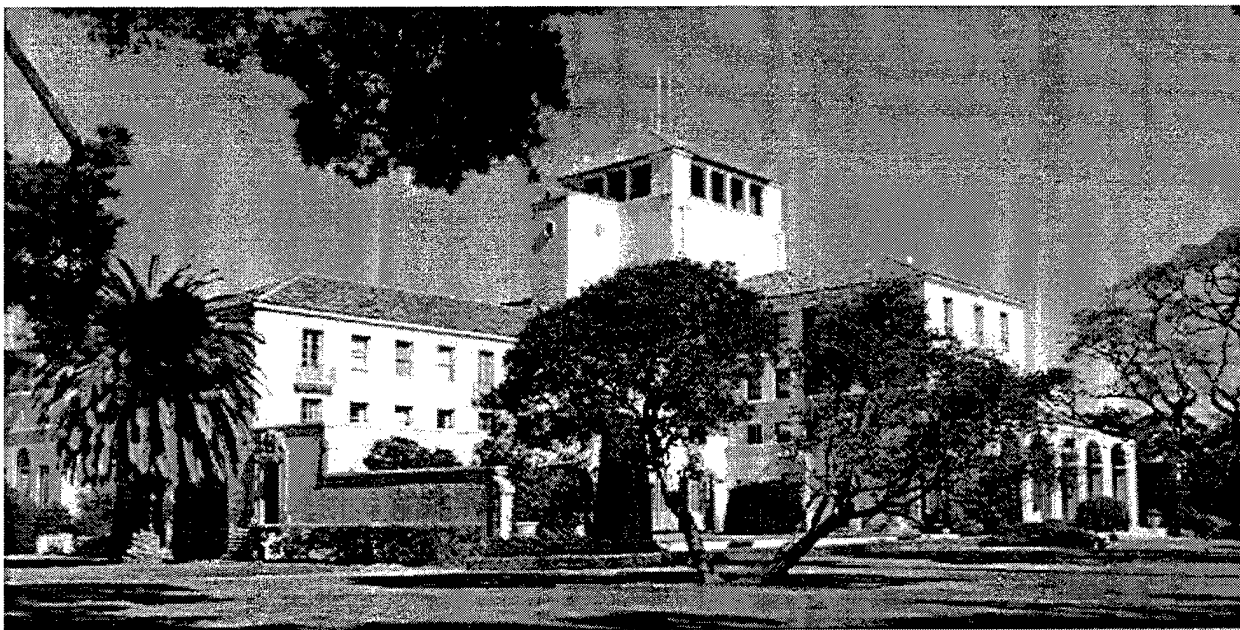
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13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Department of Computer Science. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges

CONTENTS

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, four interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Department of Computer Science during 1997. Also included is an overview of the department, faculty listing, a compilation of publications/presentations, and abstracts from theses directed by the department faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2098 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil~code09/.

INTRODUCTION

The research program at the Naval Postgraduate School exits to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.

- NPS Institutionally Funded Research Program (NIFR): The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.

- Institute for Joint Warfare Analysis (IJWA) Program: The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1997, the overall level of research effort at NPS was 151 faculty workyears and exceeded $32 million. The Department of Computer Science's effort was 11.14 faculty workyears and exceeded $2.6 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY97, over 87% percent of the NPS research program was externally supported. In the Department of Computer Science 83% was externally supported.

The department's research sponsorship in FY97 is provided in Figure 1.
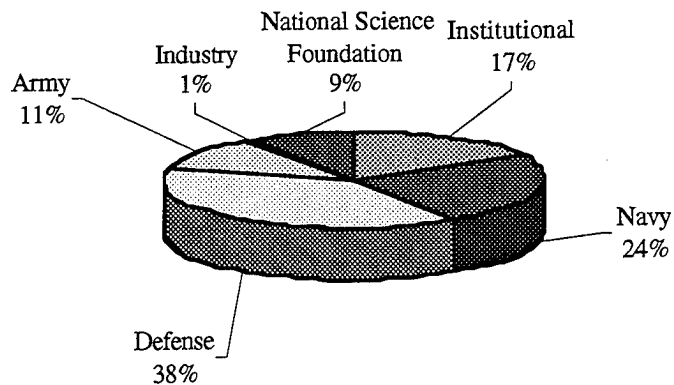
Figure 1. FY97 Sponsor Profile of the Department of Computer Science

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

January 1999

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DEPARTMENT SUMMARY

The Department of Computer Science has active research in several important areas of interest to Department of the Navy. A description of the major areas follows.

Software Engineering

Professor Luqi's research is to enable rapid prototyping of hard real-time systems via a Computer-Aided Prototyping System (CAPS). CAPS is based on a prototyping language with module specifications for modeling real-time systems and combining reusable software. These tools make it possible for prototypes to be designed quickly and executed to validate the requirements. The research focuses on automated methods for retrieving, adapting, and combining reusable components based on normalized module specifications; establishing feasibility of real-time constraints via scheduling algorithms; simulating unavailable components via algebraic specifications; automatically generating translators and real-time schedules for supporting execution; constructing a prototyping project database using derived mathematical models; providing automated design completion and error checking facilities in a designer interface; and establishing a convenient graphical interface for design and debugging.

Rapid prototyping is a means for stabilizing and validating the requirements for complex systems by helping customers visualize system behavior prior to detailed implementation, e.g., for embedded control systems with hard real-time constraints. CAPS supports an iterative prototyping process characterized by exploratory design and extensive prototype evolution. This should enable the first production version of the software to match user needs and reduce the need for expensive modifications after delivery. The current version of CAPS has been used to generate a software prototype of a C31 system with hard real-time constraints. The preliminary result of such an approach has shown great promise.

The major objective of Professor Shing's research is to develop efficient algorithms and tools to support the computer-aided rapid prototyping of real-time embedded systems. The process of design and development of real-time embedded systems is often plagued with uncertainty, ambiguity, and inconsistency. The timing requirements are difficult for the user to provide and for the analysts to determine. It is also very difficult to determine whether a delivered system meets its requirements. Rapid prototyping provides a means to alleviate the risks and difficulties in real-time embedded systems.

Specific topics Professor Shing is investigating include efficient heuristic scheduling algorithms for real-time systems, and incremental attribute-evaluation and software architectures for distributed real-time embedded systems.

Formal methods and associated automated decision aids have a large potential for practical impact that has not been fully realized. To help bring this about, Professor Berzins has developed a formal specification language specifically designed for large-scale applications that include parallel, distributed, and real-time systems. He is currently investigating a variety of methods and tools for partially automating many aspects of software development.

Professor Berzins seeks to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in development and maintenance of large software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

Professor Berzins has also investigated change merging for specifications and for software prototypes of real-time systems. He integrated a change merging mechanism for specifications with an inheritance mechanism and investigated both applications and formal properties of the resulting structure. He has been working on an analog of the program slicing method for the PSDL language. PSDL presents new problems because it includes explicit real-time constraints and parallel operations. He has also designed an automated design management and job assignment system. The main advance provided by this system is automated scheduling and job assignment for teams of engineers in an environment where plans are uncertain, partially known, and subject to change while the work is in progress.

Professor Shimeall's interests center around a consistent view of the analysis of software. During the development of software there are a variety of properties that must be applied and validated to the software, including correctness, safety, security, and modifiability. While these properties are very diverse, there are a set of approaches that are shared in the validation of these processes.

Professor Shimeall's research has identified three basic approaches to the analysis of software with respect to the above properties: similarity, individuality and source-affinity. Tools have been constructed to apply these approaches to software: Similarity: Reacher - reachability condition analyzer; Falter - activation condition annotator; Spacer -propagation condition analyzer; viewer - user interface to the similarity toolset; Individuality: ITIE - fault/event tree graphical editor; FT2PN - fault tree/Petri net converter; PN2FT - Petri net/fault tree converter; ACT'T - Ada/fault tree converter; Source-affinity: Tparse/An – variable-initialization analyzer; AAPSLC - Ada physical source line counter. Taken together, these tools provide a flexible framework for addressing the analysis of a variety of software properties, and they have been applied to several systems to examine correctness, safety and modifiability concerns. Work in progress includes extending the functionality of these tools, adding additional tools to automate other analysis phases and applying these tools to security and other software properties.

Programming Languages and Foundations

Programming languages play a fundamental role in computing. Well-designed languages are important to a wide variety of areas, including software engineering, modeling and simulation, databases, security, and distributed systems. There are few areas of applied computer science that do not benefit directly from a programming language in some way. Advances in the theory and implementation of programming languages therefore have a very broad impact on applied computer science.

To reason about a system whose operating software is written in some programming language, one needs the ability to reason about its programs. For this purpose, we need a formal semantics for the language and perhaps a programming logic, proven sound with respect to that semantics. Traditional programming logics have gone largely unused in practice because of the effort required to formulate the proper correctness criterion and then to prove it. However, there are "light" logics that are domain specific. Their aim is to make proving specific properties of programs easier. Such properties include reasoning about synchronization behavior among processes on a parallel machine, program termination, memory leaks, and even leaks of classified information. Light logics are more likely to be decidable, meaning a machine can answer, for a given piece of code, whether the code has a desired property.

Part of the Advanced Type Systems in Computing Project at NPS is concerned with developing a light logic for privacy in programs. The logic allows one to reason about a program's ability not to leak sensitive information. The logics are decidable type systems. As such, algorithms exist for performing privacy type inference.

Another major thrust of the project is to identify the rudiments of a programming language. This requires formulating appropriate security and safety properties so that one can prove, with respect to a formal semantics, that certain programs do not violate these properties. New semantic techniques have been developed for this purpose.

The programming languages and foundations effort at NPS is headed by Associate Professor Dennis Volpano.

Computer Graphics and Visualization

The NPSNET Research Group has a decade of experience in developing the software, interaction and networking technology for the large-scale virtual environment (LSVE). The current group (Michael Zyda, Don Brutzman, Rudy Darken, Robert McGhee, John Falby, Eric Bachmann, Kent Watsen and Russell Storms), is focusing on the LSVE network software architecture, web-based interoperability, cross-platform VE toolkits, 3D VE construction, inertial motion tracking, locomotion devices, human modeling in the VE, spatial sound, wayfinding in the VE, and DoD applications of VE technology.

The focus of the NPS Research Group is on the complete breadth of human-computer interaction and software technology for implementing large scale virtual environments (LSVEs). The research is applied to constructing virtual environments useful for the Department of Defense.

The NPSNET Research Group has three main branches, Technology, Interaction, and Applications. The Techno branch focuses on developing the network and software technology for the LSVE. The Interact branch focuses on human-computer interaction technology for the LSVE and on the evaluation of the LSVE for training. The Apps branch focuses on the development of LSVEs useful for the Department of Defense, utilizing the technology developed by the other two branches.

The NPSNET Research Group is a group of faculty (headed by Professors Zyda and Pratt), staff, and students that work in all areas of networked virtual environments. The research group is currently focused on the following virtual environment

(YE) research topics: the large-scale networking of virtual environments (environments greater than 1,000 players), YE network applications protocols, rapidly reconfigurable VE network protocols, Distributed Interactive Simulation (DIS) and High-Level Architecture (HLA) protocols, the real-time walkthrough of large-scale networked VEs, world modeling software for managing large scale networked VEs, the instrumentation of the human body and its representation in the networked YE, hypermedia integration (how we place video, audio, imagery and textual data in the networked YE), and geometric modeling (terrain, building and other c5ject modeling).

The NPSNET Research Group's efforts focus on the development of the above software areas and the integration of proven components of that work into a core software system, NPSNET. NPSNET is currently capable of simulating articulated humans, and ground, air and sea-going vessels in the DIS networked virtual environment. NPSNET can support about 250-300 players using currently available networking and workstation technology. NPSNET is the first 3D virtual environment that is capable of playing across the multicast backbone (MB ONE) of the Internet.

Real-time (3D) computer graphics workstations have progressed to a point where they can be used for Out The Window (OTW) visual simulation systems. The key to the development of these systems is the underlying software. As with most leading edge technologies, the construction of the required software is a black art. As such, the focus of the research has been the development, documentation, and distribution of workstation based OTW visual display systems. A major component of this research is the distribution of the simulation across the network. This allows multiple users to interact with each other in a virtual environment. This is one of the key premises of DIS, inserting humans into the virtual environment where they can "free-play" different scenarios. While this sounds simple, the problems of networks, human/computer interfaces, and data management are significant research topics. While the humans in the virtual environment comprise an integral component of the system, there are not enough manned simulators to sufficiently populate the world.

To provide the additional entities, Professor Pratt is conducting research in the use of traditional constructive combat models and autonomous agents to populate the world. By providing an interface to the traditional models, the work that has been done before in combat modeling can be leveraged. This, combined with the research on autonomous agents, provides a mechanism to provide friendly and opposing forces to complement the manned simulators.

While virtual environments (YE) are gaining widespread notoriety as a training tool and general interface to information spaces, little research has been done to show that this technology is in fact useful for training or that it represents an improved interface over conventional techniques.

One of the fundamental obstacles involved with large information spaces and most VE simulators is that of user disorientation. Users cannot navigate a virtual space as well as they can a real space. Professor Darken's interests in this problem come from two different perspectives: (1) navigation aids to improve users' performance on navigation tasks in VEs, and (2) navigation training aids to improve users' performance on real world navigation tasks trained in the YE. Another aspect of this problem has to do with locomotion techniques available to users. Currently, there is no way for a user to walk naturally in a large YE. There are encumbering cables and limited space in which the user must operate. We have recently evaluated a device (the Omni-Directional Treadmill) that attempts to overcome this limitation.

It has recently been shown that we receive more information aurally than we are consciously aware of. In fact, it is believed that sound has a large impact on training effectiveness in VEs. Professor Darken is beginning a research program to investigate this issue within the context of air training. In this, "the information age," it is somewhat surprising that we allow ourselves to be chained to a desk, staring at a monitor and typing on a keyboard. Professor Darken believes usability in computing is not just a matter of how we do things with computers but where we do things with computers. The objective here is to develop a wireless mobile computing environment where information is where users need it when they need it. There is a strong overlap between this and YE research as what we- learn about usable interfaces to virtual spaces can be applied to building usable interfaces to real spaces such as ship compartments, buildings, towns, and the battlefield.

One of the key components of a military virtual environment is the geometric description of the terrain database. To address the importance of the terrain database, NPSNET has active research projects in the areas of terrain modifications, culling, and polygon reduction. NPS is quickly becoming one of the leading organizations within DoD for the understanding and conversion of terrain database formats.

Research for the development of highly realistic tactical battlefield simulation systems by Professor Baer is organized around three main areas. These are: (1) development of algorithms for visualizing realistic battlefield effects including 1 meter or better terrain backgrounds, photo realistic targets, and environmental effects and battlefield; obscurants, (2) development of database generation and update systems designed to reduce instrumentation, photographic, and video data to object-descriptor data bases, and (3) development of high speed low cost parallel-processor technologies in order to execute the algorithms and systems resulting from the two previous research areas.

Artificial Intelligence and Robotics

The major objective of Professor Kanayama's research is to investigate fundamental theories in autonomous mobile robotics. Since autonomous self-contained robots have complete freedom in motion, the topic is fundamentally interesting in robotics and M. Furthermore, there are tremendous opportunities for such robots to perform practical tasks in the real world. Professor Kanayama tests and evaluates theories on the Autonomous Indoor Mobile Robot Yamabico-11. Research activities cover abstract mathematical models, intelligent algorithm finding, software development, and hardware construction. Specific topics Professor Kanayama has been investigating include: a smooth vehicle tracking algorithm, sonar interpretation, rigid body motion planning, automated cartography, vehicle control by a steering function, a high-level mobile robot language MML, a real-time hardware/software architecture for mobile robots, motion planning for an autonomous underwater vehicle, and fast gait planning for an underwater walking robot.

The role of robotics in manufacturing is already well established and is an important factor in increasing industrial productivity. In contrast, the introduction of robots into military operations has just begun. This is due in part to justifiable concerns about removing human control from potentially lethal systems, but perhaps to a greater extent is the result of the relatively weak capabilities of mobile robots operating in the unstructured or even hostile environments typical of military situations. Professor McGhee's research is concerned with adapting existing robot technology to suit military applications, and with making theoretical and engineering advances in areas where current knowledge is inadequate for a selected application. He pursues this goal both through the construction of prototype systems for concept demonstration, and by means of real-time graphical dynamic simulation studies in support of such research.

With the recent rapid increase in interest in networked interactive simulations as an alternative to actual field exercises, the accurate modeling of vehicle dynamics needed for mobile robot design studies has taken on a new and larger urgency. At present, Professor McGhee's research is centered around the application of unmanned submersibles to mine countermeasures. Both swimming vehicles and walking vehicles are being considered for this purpose. In the first instance, the NPS Autonomous Underwater Vehicle (AUV) is available for experimental studies. In the second, various vehicles derived from his earlier research on terrestrial walking machines are being considered. Accurate simulation models are being used in both cases to permit not only concept evaluation, but also the development of real-time control software through "hardware in the loop" simulation studies.

The MARIE project of Professor Rowe seeks to build an information-retrieval system for large multimedia databases that exploits the contents of the multimedia. This requires image processing, but especially natural-language processing since descriptive captions are often associated with valuable multimedia data and are much faster to analyze than images. MARIE exploits a large technical lexicon and a trainable statistical parser using statistics on word senses, syntactically-grouped word-sense pairs, parse rules, and rhetorical heuristics. MARIE's image processing uses robust natural-image segmentation methods, together with a neural network for classifying regions; the network also exploits linguistic reference information. MARIE also addresses system-building issues for large multimedia databases by considering the problem as one of efficient information filtering of desired data. Professor Rowe has developed mathematical criteria for optimal such information filtering, including data-par~llel implementations.

The METUTOR project of Professor Rowe helps teachers write and run tutors for tasks involving sequences of actions. With METUTOR, tutors are considerably easier to build than with conventional frame-based tools, while at the same time being smarter in analyzing student behavior. METUTOR tutors use planning methods of artificial intelligence to figure out what a student is trying to do, which gives powerful inference capabilities for finding student errors, categorizing them, and tutoring them. METUTOR permits mapping of domain concepts to graphical elements, which are then combined into a visual display of domain state.

Professor Rowe also conducts research in construction of universal (all-situations) plans for robots moving in natural domains. These are like potential fields but better: They give the provably best thing to do in any situation.

Parallel, Distributed, and Network Computing

Designers of high performance computing systems are increasingly turning to parallel processor systems to achieve high speed at relatively low cost. In such a system, processing elements are duplicated (numbering in the hundreds or thousands) and often the memory is distributed to support parallelism. While the hardware has been rapidly improving, the software for such machines is still archaic. There is no agreement on how to program these machines, nor on the best way to design a

parallel programming language, compiler, operating system, or application program. Thus, the central focus of Professor Lewis' research has been in the design and development of parallel programming environments which support architecture-independent parallel programming.

Recently, in a joint research project between NPS and the Russian Academy of Sciences Systems Programming Institute in Moscow, Russia, Professor Lewis is designing and implementing a parallel programming environment called mpC. This is a language, translator, and scheduling system for automatically mapping a parallel program written in mpC onto an arbitrary parallel computer. The network features of mpC permit rather general expression of the solution to a problem in terms convenient to the programmer. But this may be non-optimal use of the parallel hardware. Therefore, scheduling tools are needed to optimize the performance on a specific machine.

The hardware necessary to create a meta-computer has existed for twenty years. Likewise, heterogeneous programs-consisting of multiple parts, each running in a predefined sequence and on potentially different machines-have been around since the Sixties; these programs have been very latency-tolerant, meaning that the results from one part of a program often had to be written to tape and hand carried to another computer where the next part would execute. The demands of today's environments, particularly that of the military world, can no longer tolerate these latencies. In a crisis situation, where data acquisition, transfer, computation, and display must happen within minutes to be of any use, traditional methods have become outdated and, indeed, dangerous. At a basic level, a meta-computer is a distributed and heterogeneous collection of computers networked together, all coordinated by one or more master schedulers. Such a meta-computer can potentially, and in a matter of minutes, process a request from a hot spot, acquire the data from satellite, compute in a secure facility in the U.S., and present the results to the field commander somewhere in the Middle East. In addition, the meta-computer might be processing hundreds of such requests simultaneously.

Professor Kidd's research generally involves the architectural design of such a meta-computer. To this end, he has created the Heterogeneous Processing Testbed (HPT) in the Heterogeneous Processing Laboratory (HPL). The HPL supports research in meta-computing and heterogeneous processing by providing a fully controlled environment for testing, development and evaluation.

In a distributed and heterogeneous environment, two of the biggest issues are where and when to schedule jobs. Though seemingly settled for "single box" architectures, it is far from solved in a distributed environment, especially one which combines many "boxes" of highly varying architectures. Some of the issues Professor Kidd's research attempts to address are: (1) what optimization criteria should we use, (2) how do you schedule jobs to meet various constraints on when and where they are to execute, such as job A must execute in parallel with job B and before job C, (3) how do you avoid resource contention related to the sharing of resources, such as disks, CPUs and networks, by different jobs, and (4) how do you meet the optimization criteria.

One ingrained assumption underlying Computer Science is determinism. Though never completely true, it has been "good enough" in traditional architectures. As the development of distributed computer evolves, determinism is no longer a valid assumption/simplification. Uncertainties derived from various sources, such as network traffic, shared disk use, and cache use, make job runtimes and other time related events better represented by a probability distribution. To this end, Professor Kidd and Professor Hengsen's research applies probabilistic and statistical techniques in scheduling and learning.

Professor Hensgen is one of the Principal Investigators for the Management System for Heterogeneous Networks (MS HN) Project, sponsored by DARPA under its Quorum Project. This research for MSHN is conducted by several faculty members here at NPS (Hensgen, Kidd, and Irvine), staff and students here at NPS, as well as researchers at NRaD, Purdue, and the University of Southern California. The goal of MSHN is to deliver good end-to-end quality of service to users in environments where both the heterogeneous resources and user set are dynamically changing. MSHN will serve a mixture of applications ranging from compute-intensive to I/O-intensive to interactive and real-time. Professor Hensgen's main area of research within the MSHN project is prioritized management of the multiple shared resources. In particular, it is extremely important to carefully model various classes of shared computing resources which differ greatly from other resources which we typically share.

In addition to the MSHN project, Professor Hensgen and some of her students participate in NRaD's SmartNet project, a scheduling advisor for heterogeneous computing resources. SmartNet has been used within DoD for compute-intensive jobs and the NPS team is currently investigating something similar for communication-intensive jobs.

With her students, Professor Hensgen has also built Graze, a graphical, performance debugger for parallel computing and Concurra, a software system that generates multi-threaded applications whose concurrency is provably correct and which are free from deadlock. One of her current students is investigating the use of Graze to monitor Java programs as well

as its use in determining when certain compiler directives should be used with automatically parallelizing compilers. This will be useful to applications being written for FLEETNUMERIC and the Pacific Disaster Center.

Professor Lundy's research interests are in telecommunications networks and computer networks generally. Most of this work has been in the specification, analysis and testing of communications protocols. This often leads him to suggestions for possible improvements of existing protocols, correcting errors in them, or both. Recent work is in high speed transport protocols, multicasting protocols for reliable communications, and wireless protocols. Professor Lundy is also interested in military communications and in network security. In the past year, Professor Lundy has been studying and evaluating some of the U.S. Army's current networks and their future plans for these networks.

Network guarantees of quality of services required for the transport of multimedia data such as digital audio and video. Specifically, end-to-end transfer delays and loss rate of a multimedia data flow must be bounded below specified values. The objective of Professor Xie's research is to design networks that provide these guarantees. During the past two years, Professor Xie has developed a new network architecture (called Burst Scheduling network), and a set of algorithms for providing end-to-end delay guarantees. The algorithms are highly efficient, suitable for high speed implementation.

Professor Xie's current focus is on the development of an application-level guaranteed statistical service. The service is characterized by: (1) a bound on loss rate of application-level data units (e.g., pictures in a video application), (2) data losses distributed fairly among flows subscribing to the service and uniformly over the duration of each flow, and (3) a deterministic traffic model that promotes statistical multiplexing in the network. More specifically, a flow is modeled as a sequence of bursts, each of which carries the bits of an application-level data unit (ADU). The first and last packet of each burst are marked, and the first packet carries information on the ADU (including the bandwidth requirement). The traffic model enables admission control at the burst level as well as the flow level. To achieve high network utilization, overbooking is allowed in flow level admission control. Burst level admission control, on the other hand, is used to ensure that the capacity of each network channel is not exceeded by bandwidths allocated to flows such that delay guarantees can be provided. The guaranteed statistical service will greatly enhance the ability of existing networks to support distributed multimedia applications such as remote teaching and video on demand.

Computer Security

As the value of the assets stored in computer systems increases, attacks by highly motivated, technically capable opponents using malicious software and subversive techniques become more likely. A scientific foundation exists which may be employed to build secure computer systems and certified software to protect sensitive information. Several areas of research are being pursued.

The widespread use of commercial off-the-shelf (COTS) platforms enforcing security policies with a high level of assurance has been hampered by a lack of compatibility with existing COTS and government-off-the-shelf applications software. Trusted file system research is intended to permit the use of both high assurance security policy-enforcing platforms and the massive body of application software currently available. Professor Irvine's government-industry team plans to build a prototype system providing high assurance controlled sharing of information while allowing users to continue to run their favorite COTS workstation applications. An extension to the initial effort would be the development of a high assurance messaging capability permitting the selection of cryptographic keys and methods based on information security levels.

The use of covert techniques to export sensitive information from trusted systems is also being explored by Professor Irvine. This research will include the analysis of encoding techniques for exploitive purposes as well as empirical studies of the efficacy of these covert techniques.

Databases

Professor Wu's main research interest is in creating a unified database front-end system that provides easy-to-use yet powerful common language to access varying types of relational data management system (RDBMS), and shields the complexity of underlying RDBMS. His system called GLAD II (Graphics Language for Accessing Database) allows users to interact with different relational DBMS by providing a common graphic language called DFQL (Data Flow Query Language) that is based on a data flow diagram. The system automatically translates a user specified DFQL query into the

equivalent query statements recognized by the connected backend DBMS. At present, the prototype connects to Oracle and translates the DFQL queries into the Oracle's SQL statements.

Professor Wu's work is different from other similar-looking work and commercial products in that theirs only support a SQL connectivity, i.e., theirs do not shield users from the complexity of SQL. In contrast, DFQL provides a more logical, higher-level, and consistent query language. Users of DFQL do not have to bother with the poorly designed language features in SQL. In other words, theirs do not eliminate the semantics problem associated with data retrieval. DFQL is a graphic query language based on relational algebra. It has been designed with sufficient expressive power and functionality to allow the user to easily express database queries. DFQL is relationally complete and includes an implementation of aggregate functions. An object-oriented implementation allows programmers to easily create their own DFQL operators from the primitive and other existing user-defined operations. This extensibility of query language is unique, no other query language allows such extensibility. The overall intention is to provide the user with a simple-to-use, yet powerful and extensible tool to implement database queries. A human-factors analysis comparing DFQL and SQL showed DFQL was statistically better than SQL.

POWERPC OPTIMIZATION FOR REAL-TIME SCENE GENERATION: PARALLEL RENDERING FOR ENVIRONMENTAL SUPPORT OPTV2 DEVELOPMENT AND DATA SUPPORT DISTRIBUTED INTERACTIVE SIMULATION TECHNOLOGIES IN AFTER-ACTION REVIEW SUPPORT (DISTAR)

Wolfgang Baer, Research Assistant
Department of Computer Science
Sponsor: U.S. Army Test and Experimentation Command and PARSYTEC, Inc.

OBJECTIVE: Development of Sensor Realistic Real-Time Battlefield Simulator on commercial off-the-shelf (COTS) PC Equipment.

SUMMARY: Research during 1997 concentrated on the development of parallel ray trace algorithms for rapid generation of video realistic tactical battlefield simulation in a symmetric multiprocessor pentium- based PC. Research activities included the development of benchmark tests of networked pentium-based machines under the Linux and NT operating systems to determine the feasibility of using low cost commercial components to host high speed simulations. Specifically, the questions of rapid access of large arrays in main memory of symmetric multiprocessing configurations and efficient cache utilizations were addressed.

PUBLICATIONS:

Baer, W., "Real-Time Scientific Rendering Simulation for General Sensors," Spring Simulation Interoperability Workshop, Workshop Papers, IST-CF-97-01.2, IST, Orlando, FL, Vol. I, p. 535, 3 March 1997.

CONFERENCE PRESENTATION:

Baer, W., "Real Time Scientific Rendering Simulation for General Sensors," Spring Simulation Interoperability Workshop, Orlando, FL, March 1997.

THESIS DIRECTED:

Decato, S. W., "Parallel Processing Performance Evaluation of Mixed T10/T100 Ethernet Topologies on Linux Pentium Systems," Master's Thesis, Naval Postgraduate School, March 1997.

OTHER:

Baer, W., "Software Performance Modeling in PC Clusters," 6SMP Performance Analysis for Battlefield Visualization, 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Battlefield Simulation, Parallel Processing, Ray Tracing

TASK FORCE XXI DATABASE SUPPORT SMART GRID TO VECTOR CONVERSION TERRAIN DATABASE CONVERSION TOOLS FOR JANUS/PEGASUS/MODSAF

Wolfgang Baer, Research Assistant
Department of Computer Science
Sponsor: U.S. Test and Experimentation Command and U.S. Army Training and Doctrine Analysis Command, Monterey

OBJECTIVE: Develop rapid terrain database generation capability on low cost PC equipment.

SUMMARY: Development of a terrain data creation toolbox which allowed standard data sources (DTED and SPOT) to be integrated with high resolution aerial photographs was expanded to allow input of commercial high resolution digital elevation data, local photography, and battlefield data sources. The toolbox research provides for rapid terrain generation including automated pattern recognition, stereo elevation extraction, and model-based feature identification. The utilization of image differencing as an approach for rapid terrain generation is one of the central themes of this research.

PUBLICATION:

Baer, W., "Toward Standards for Interoperability Simulation Reuse for Infrared (IR)," Fall Simulation Interoperability Workshop, Workshop Papers, IST-CF-97-043, IST Vol. II, p. 983, Orlando, FL, 8-12 September 1997.

CONFERENCE PRESENTATION:

Baer, W., "Toward Standards for Interoperability Simulation Reuse for Infrared (IR)," Fall Simulation Interoperability Workshop," Orlando, FL, Fall 1997.

DoD TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Terrain Database, Pattern Recognition, Machine Vision

BINARY UNIVERSAL METEOROLOGICAL DATA FORMAT DEVELOPMENT PHASE II
Wolfgang Baer, Research Assistant
Department of Computer Science
Sponsor: Naval Research Laboratory-Monterey

OBJECTIVE: Development of meteorologic encoder for the Naval Research Lab in Monterey.

SUMMARY: This contract was the second phase of a software design and development project leading to the delivery of an operational encoder for transmission of WMSO standard data known as GREB and BUFFER. These formats represent variable field and message information. The research required to develop efficient coding schemes for self-descriptive compact transmission of large arrays an sparse matrices.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Meteorology Data Standards, Data Transmission Format

SOFTWARE REASONING FOR COMBINING CHANGES TO SOFTWARE SYSTEMS
Valdis Berzins, Professor
Department of Computer Science
Sponsor: U.S. Army Artificial Intelligence Center

OBJECTIVE: The goal of the project is to apply previously developed theories of software design structure and develop a prototype decision support tool for software maintenance in the context of the Computer-Aided Prototyping System (CAPS).

SUMMARY: In 1997, the project completed the implementation and evaluation of a method for combining changes to hierarchical design structures. This method is the first of its kind with the ability to automatically detect and automatically recover from conflicts between the independently developed changes to be combined. This is possible in this context because of the following special characteristics of hierarchical software design structures: (1) the extension of the design structure lattice to a Brouwerian algebra preserves the least upper bounds of the original lattice and (2) the semantics of the

design (although not its understandability) is independent of the hierarchical structure. The first property ensures that reasoning in the extended algebraic structure is also valid with respect to the embedded model of proper designs, and the second ensures that weakening approximations with respect to the lattice structure do not throw away practically vital information.

The initial experimental assessments of the implementation indicate that the method is computationally tractable and produces reasonable results. The project has also developed a method for merging changes to black-box specifications for software modules, expressed using logic [Berzins 98]. This introduces a boolean difference operator into the logic, which has not been extensively studied and has somewhat surprising properties. Experience with applying the method shows that changes that intuitively seem independent may not actually be independent. The conjecture is that this may be relevant to the feature interaction problem in software requirements.

PUBLICATIONS:

Berzins, V., "Recombining Changes to Software Specifications," to appear, *Journal of Systems and Software*, August 1998.

Berzins, V., "Merging Changes to Software Specifications," *Proceedings of the 1997 ARO Workshop on Requirements Targeting Software and System Engineering - Towards a Scientific Basis*, Munich, Germany, 12-14 October 1997.

Leonard, T., Berzins, V., Luqi, and Holden, M., "Gathering Requirements from Remote Users," *Proceedings of the 9th International Conference on Tools with Artificial Intelligence*, Newport Beach, CA, 3-8 November, 1997, pp. 462-471.

Luqi and Berzins, V., "Engineering Automation for Computer Based Systems," *Proceedings of the 1997 Workshop on Virtual Universities*, Newport Beach, CA, 4 November 1997.

CONFERENCE PRESENTATIONS:

Luqi, "Merging Changes to Software Specifications," Army Research Office Workshop on Requirements Targeting Software and Systems Engineering, Bernried, Germany, 13 October 1997.

Luqi, "Why Worry about Change Merging?" Workshop on Virtual Universities, Newport Beach, CA, 4 November 1997.

THESIS DIRECTED:

Keesling, W., "Decomposition Recovery Extension to the Computer-Aided Prototyping System (CAPS) Change-Merge Tool," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Automated Reasoning, Software Evolution, Conflict Resolution

REQUIREMENTS ANALYSIS FOR CVX
Valdis Berzins, Professor
Department of Computer Science
Sponsor: Naval Sea Systems Command

OBJECTIVE: This goal of this research is to reduce the risks of the CVX effort via analysis of selected aspects of the requirements. The current requirements for the CVX have been prioritized using the QFD method, which is based on the Analytic Hierarchy Process (AHP) method. Recent work at the Naval Postgraduate School has applied the AHP method in the context of software requirements and has developed a number of improvements. The objectives of the project is to apply the CVX data to the several improved algorithms for the AHP method developed at the Naval Postgraduate School and compared the results to those of the original study.

SUMMARY: Recent work at the Naval Postgraduate School has applied the AHP method in the context of software requirements and has developed a number of improvements. These improvements have been incorporated to the AHP method, together with the algorithm for the exact eigenvector calculations in the MATLAB program. The software developed in this project provides requirements analysts with new improved algorithms to prioritize the CVX UNTL task requirements. Experimental results showed that, under the conventional linear weighting scheme, the original study produced highly accurate computations.

The exponential weighting scheme provides another way to combine the pairwise importance ratings. It was shown, by comparing the difference between the original input matrices and the reconstructed consistent matrices, that the exponential weighting scheme gives results which match the original input matrices better, in the sense that the numerical measures of degrees of inconsistency for the individual pairwise judgements are smaller. It is recommended that CVX UNTL domain experts review the priorities and ranking produced by the exponential weighting to see if they are indeed closer to human expectations. The reconstructed consistent matrices and the difference matrices for the linear weighting scheme also pinpoint potential areas of inconsistency in the original input matrices. CVX UNTL domain experts should review the results for reducing potential risks of the CVX effort.

PUBLICATIONS:

Berzins, V., "Requirements Analysis for the CVX," Project Report, CVX Program Office, 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Analytic Hierarchy Process (AHP) Software Requirements, Prototyping

AUTOMATION SUPPORT FOR SOFTWARE EVOLUTION
Valdis Berzins, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The objective of this research is to design a system for automating the configuration management needed to keep track of the evolution of a software prototyping during a typical application of the evolutionary software prototyping method supported by the Computer-Aided Prototyping System (CAPS).

CAPS is an integrated software development environment aimed at rapidly prototyping hard real-time embedded software systems, such as missile guidance systems, space shuttle avionics systems, robots, automated factories, telecommunications systems, computer-controlled vehicles, and computer-controlled consumer appliances such as microwave ovens and sewing machines.

SUMMARY: The technical objective is to create, validate, and implement an integrated set of formal models and algorithms that can be used to enable computer-aided evolutionary development of a wide-range of complex software applications, including real-time and embedded systems.

This is important for computer-aided software evolution because this type of software is particularly resistant to change, is often safety- and mission-critical, and may have to be changed on short notice when external conditions change. Unaided modifications to these systems are often times consuming and unreliable because timing constraints introduce heavy dependencies between otherwise logically unrelated parts of the software. A valid, accurate, and coherent set of formal models is a needed first step in the detailed design of the desired decision support tools.

PUBLICATIONS:

Berzins, V., "Merging Changes to Software Specifications," *Proceedings of the 1997 ARO Workshop on Requirements Targeting Software and System Engineering - Towards a Scientific Basis*, Munich, Germany, 12-14 October 1997.

Berzins, V., Ibrahim, O., and Luqi, "A Requirements Evolution Model for Computer-Aided Prototyping," *Proceedings of the 9th International Conference on Software Engineering and Knowledge Engineering*, Madrid, Spain, pp. 38-47, 17-20 June 1997.

Leonard, T., Berzins, V., Luqi, and Holden, M., "Gathering Requirements from Remote Users," *Proceedings of the 9th International Conference on Tools with Artificial Intelligence*, Newport Beach, CA, pp. 462-471.3-8 November 1997.

Luqi and Berzins, V., "Engineering Automation for Computer Based Systems," *Proceedings of the 1997 Workshop on Virtual Universities*, Newport Beach, CA, 4 November 1997.

CONFERENCE PRESENTATIONS:

Berzins, V., "Merging Changes to Software Specifications," Army Research Office Workshop on Requirements Targeting Software and Systems Engineering, Bernried, Germany, 13 October 1997.

Berzins, V., "Why Worry about Change Merging?" Workshop on Virtual Universities, Newport Beach, CA, 4 November 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer-Aided Software, Decision Support Tool

TRAINING SPATIAL KNOWLEDGE ACQUISITION USING VIRTUAL ENVIRONMENTS
Rudolph P. Darken, Assistant Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: To study navigation and spatial orientation phenomena associated with real and virtual environments and determine how virtual environments can be used to improve navigation ability in the real world.

SUMMARY: The importance of navigation and wayfinding in virtual environments is paramount to the success and eventual acceptance of this technology as an operational and training tool for the Navy. It will be shown that virtual environments can be used to acquire spatial knowledge of a specific real space. This is largely a training transfer study. The work will also involve the investigation of environmental features and perceptual stimuli and their role in navigation and wayfinding so that an understanding of how to degrade the fidelity of a virtual environment without substantially degrading navigation performance can be made. These concepts will be extended to training general navigation skills, including map usage (perspective transformation) and landmarking abilities.

PUBLICATION:

Darken, R.P., Cockayne, W.R., and Carmein, D., "The Omni-Directional Treadmill: A Locomotion Device for Virtual Worlds," *Proceedings of UIST '97*, pp. 213-221, 1997.

CONFERENCE PRESENTATIONS:

Darken, R.P., Cockayne, W.R., and Carmein, D., "The Omni-Directional Treadmill: A Locomotion Device for Virtual Worlds," UIST 1997.

Darken, R.P., "Acquiring Spatial Knowledge from Virtual Worlds," Invited lecture at the Oregon Center for Advanced Technology Education, Oregon Graduate Institute, Beaverton, OR, 21 November 1997.

Darken, R.P., "Designing for Wayfinding in Virtual Environments," Panel on Designing Interactive Multimedia, ACM Multimedia '97, Seattle, WA, 12 November 1997.

Darken, R.P., "Navigation in Virtual Environments," Course lecture in Applied Virtual Reality, SIGGRAPH 97, Los Angeles, CA, 4 August 1997.

Darken, R.P., "Wayfinding in Virtual Worlds," Invited lecture at the American Psychological Association Annual Meeting, Chicago, IL, 18 August 1997.

Darken, R.P., "Navigating in Virtual Worlds: Wayfinding and Locomotion Issues," Lecture at the NASA Ames Research Center, Moffett Field, CA, 22 May 1997.

Darken, R.P., "Navigation in Virtual Worlds: Wayfinding and Locomotion in Real and Not-So-Real Environments," Lecture at the Carnegie Mellon University Human-Computer Interaction Institute Seminar Series, Pittsburgh, PA, 16 April 1997.

Darken, R.P., "Navigation in Virtual Worlds: Performance Issues," Panel on Performance Issues in Virtual Environments, Virtual Reality Annual International Symposium (VRAIS) 97, Albuquerque, NM, 5 March 1997.

THESIS DIRECTED:

Banker, W. P., "Virtual Environments and Wayfinding in the Natural Environment," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Environments, Cognitive Science, Psychology, Training

3-D AUDITORY DISPLAYS IN AIRCRAFT SIMULATION AND TRAINING
Rudolph P. Darken, Assistant Professor
Department of Computer Science
Sponsor: Naval Air Systems Command

OBJECTIVE: To study the use of spatial acoustic displays in aviation simulation training from the perspective of pilot performance and training transfer.

SUMMARY: The aim of this research is to explore some of the basic issues necessary to integrate virtual audio technology into new and existing training systems and operational platforms in naval aviation. It has already been shown that the capability of presenting compelling, accurate 3D spatial audio in real time is possible. It has not, however, been shown that this capability can and should be used for Naval aviation training and/or operations. The working hypothesis is that the application of virtual auditory cues can enhance team performance by increasing the combatants' awareness of other participants in the simulation, both real and computer generated. To prove this concept, these auditory displays within the cockpit as well as between cockpits in a multi-user distributed interactive simulation (DIS) scenario will be integrated. This system will then be evaluated in a number of ways to determine if the hypothesis is indeed correct. At this point, a position to determine procedures for the integration of spatial audio in Naval air training and operations in a more general way will be possible.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Environments, Cognitive Science, Psychology, Training

TRAINING NAVIGATION USING VIRTUAL ENVIRONMENTS
Rudolph P. Darken, Assistant Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: To study navigation and spatial orientation phenomena associated with real and virtual environments and determine how virtual environments can be used to improve navigation ability in the real world.

SUMMARY: The importance of navigation and wayfinding in virtual environments is paramount to the success and eventual acceptance of this technology as an operational and training tool for the Navy. It will be shown that virtual environments can be used to acquire spatial knowledge of a specific real space. This is largely a training transfer study. The work will also involve the investigation of environmental features and perceptual stimuli and their role in navigation and wayfinding so that an understanding of how to degrade the fidelity of a virtual environment without substantially degrading navigation performance can be made. These concepts will then be extended to training general navigation skills, including map usage (perspective transformation) and landmarking abilities.

THESIS DIRECTED:

Banker, W. P., "Virtual Environments and Wayfinding in the Natural Environment," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Virtual Environments, Cognitive Science, Psychology, Training

WARRIOR NETWORK EXPERIMENTS
John Falby, Lecturer
David Pratt, Associate Professor
Paul Barham, Computer Specialist
Department of Computer Science
Sponsor: Simulation, Training, and Instrumentation Command

OBJECTIVE: The graphics and video laboratory of the Department of Computer Science at NPS is currently conducting research on inserting articulated human ICONS into distributed interactive simulation (DIS). The work on Warrior Network is focused on dismounted infantry tasks using a mobility platform for the human/computer interaction

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Graphics, Computer Networks, Human Factors

SCHEDULING ATM TRAFFIC FOR BATTLEFIELD AWARENESS AND DATA DISSEMINATION (BADD)
Debra Hensgen, Associate Professor
Department of Computer Science
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: To simulate several heterogeneous scheduling algorithms and a split IP protocol in the Battlefield Awareness and Data Dissemination (BADD) ATM environment using OpNet. To determine which algorithms permit the environment to deliver acceptable quality of service. Two students, Clark Benton and Michael Lemanski were involved as well.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Heterogenous, Distributed, Networking, Simulation

HETEROGENEOUS PROCESSING PROGRAM INITIATIVE
Debra Hensgen, Associate Professor
Taylor Kidd, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: To build software, with students, for acquired hardware to establish a high quality, military-relevant, heterogeneous processing program at the Naval Postgraduate School. The goal is that after the first two years, the program will be well known for its significant achievements, will produce results that will make computing/networking a stronger force multiplier, and will be self-sustaining.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications, Modeling and Simulation, Other (Metacomputing)

KEYWORDS: Heterogeneous, Distributed, Parallel, Processing, Metacomputing

ADVANCED CONTROL SOFTWARE ARCHITECTURE FOR AUTONOMOUS VEHICLES
Michael Holden, Commander, USN
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: To produce advanced control software for autonomous vehicles within the framework of structured software engineering. This proposed research work is in advanced control software for autonomous vehicles within the framework of structured software engineering, especially as it pertains to combining the ongoing work of the NPS Computer-Aided Prototyping System (CAPS) and the Center for Autonomous Underwater Vehicle (AUV) Research.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft, Computing and Software, Human Systems Interface

KEYWORDS: Software Engineering, Robotics, Autonomous Underwater Vehicles

SUPPORT FOR INFORMATION WARFARE-PROTECT (IW-P) PROGRAM IN THE NAVAL POSTGRADUATE SCHOOL (NPS) CENTER FOR INFORMATION SECURITY RESEARCH (CISR) COMPUTER SECURITY LABORATORY
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: Naval Security Group

OBJECTIVE: The objective of this research is to support classes and thesis research in the area of information warfare-protect (IW-P) through the acquisition of laboratory equipment for the Naval Postgraduate School Center for Information Systems Security (INFOSEC) Studies and Research. Emphasis has been placed upon the initiation of research into network security issues associated with switches and routers using ATM technology with IP-tags. This is an ongoing project.

SUMMARY: Several security vulnerabilities in ATM technology with IP-tags have been identified. In this ongoing research effort, conducted with G. Xie of the Naval Postgraduate School's Computer Science Department, and two thesis

students, the development of protocols and protection techniques which can insure the confidentiality and integrity of ATM connections are being investigated. A small ATM network is being established in the Computer Security Laboratory which will allow examination of performance characteristics of the protocols being investigated.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Network Security, Active Networks, INFOSEC

AN ENVIRONMENT FOR DEVELOPING SECURE SOFTWARE
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This work is part of a continuing project aimed at developing new techniques for statically analyzing code, that is targeted for remote execution, for secure flow violations. The algorithm will attempt to construct a proof, for a given program, in a sound flow logic, thereby establishing that the program is secure. The algorithm will permit remote code, written in Web-based languages like Java and JavaScript, to be analyzed prior to execution in order to determine whether it can be executed safely.

SUMMARY: In 1997, Volpano and Smith (Florida International University), completed a decidable secure flow logic for a core imperative language with procedures. The logic is a type system with subtyping that arises due to treating upward information flow. Interesting subtype relationships exist. For instance, the subtype relation is covariant in expression types, but contravariant in command (statement) types. A type inference algorithm was developed for the logic. Type inference in this setting is interesting due to procedures which have principal types that effectively document how these procedures can be called securely in some context. The algorithm was proved sound and complete relative to the logic, and prototyped by Smith in Scheme.

PUBLICATION:

Volpano, D. and Irvine, C.E., "Secure Flow Typing," *Computers and Security*, Vol. 16, No. 2, pp. 137-144, 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Programming Languages, Information Flow

DEVELOPMENT OF INFORMATION SYSTEMS SECURITY (INFOSEC) COURSEWARE AND VIDEOS
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: Defense Information Systems Agency

OBJECTIVE: This project is to support the development of an INFOSEC course entitled Management of Secure Systems and the transformation of video tapes of the Invited Lecture Series on INFOSEC topics into Web-based material that can be exported beyond the Naval Postgraduate School to DoD, U.S. Government, and academia. The second aspect of the project is of a continuing nature.

SUMMARY: A course entitled, "Management of Secure Systems," has been developed and class sections were taught in both the summer and fall quarters of calendar year 1997. A laboratory involving a risk assessment is an integral part of the course. Two local institutions permitted students to conduct risk assessments of networked systems: California State University at Monterey Bay and Fleet Numerical Meteorology and Oceanography Center.

This research also provided partial support for the ACM Workshop on Education in Computer Security, held in January 1997. International in scope, the workshop described the relationship between academe and industry in the area of INFOSEC education. Academic programs ranged from those addressing ethics to highly technical studies in computer science. Challenges identified included formulating courses and curricula, development of classroom materials, and career prospects in INFOSEC.

A series of lectures on INFOSEC topics were video taped. Techniques to place all or portions of the lectures on the World Wide Web were investigated. These included the digitization of the videos, video editing, and presentation formats such as HTML, compact disk, and edited videos. Video editing permits a broad range of compression and enhancement options. Recommendations were made for balancing the video and audio parameters against memory and remote delivery requirements.

PUBLICATION:

Irvine, C.E., "The First ACM Workshop on Education Computer Security," *ACM Special Interest Group on Security and Audit Control Review,* Vol. 15, No. 2, pp. 3-5, 1997.

THESIS DIRECTED:

Umentum, B., "Mass Dissemination of INFOSEC via the World Wide Web," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Network Security, High Assurance Systems, INFOSEC, Education, Research

SUPPORT FOR NAVAL POSTGRADUATE SCHOOL (NPS) INFORMATION SYSTEMS SECURITY (INFOSEC) RESEARCH PROGRAM, PHASE II
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The objective of this research is to support the development of a Center for Research and Education in Information Systems Security at NPS. The effort is intended to provide military officers basic and advanced education in the area of computer and information system security. This continuing program is intended to be a continuing source of high-quality information systems security research focussing on problems of critical importance to military services.

SUMMARY: In support of research, this on-going project permitted a requirements specification and high level architecture to be developed for a multilevel local area network (LAN). A key feature of this network will be the concentration of security policy enforcement for critical mandatory policies in a high assurance server based upon an existing high assurance commercial-off-the shelf product. Client workstations will be untrusted and will run popular commercial operating systems and commercial office productivity products. A key element in the LAN design is the establishment of a trusted path between the client and the server to provide high confidence authentication of the user to the system and of the system to the user. The use of a specialized controller card at the clients was identified as an effective technique to provide secure initialization, trusted path, and object-reuse services for client workstations.

Mail services were explored as an application suitable for adaptation to a multilevel client-server environment. A mail spooler was modified to provide a concept demonstration of multilevel mailboxes hosted on a high assurance platform enforcing a mandatory security policy.

A second investigation pursued under this research program was an analysis of commercially available encryption products for the protection of information designated as sensitive but unclassified (SBU). This includes information such as personnel records, medical data, and legal records, which must be protected in order to comply with the Privacy Act. A

result of this investigation was the development of an evaluation procedure for commercial encryption products. Using the procedure, products were scored using a variety of technical, ease-of-use, and service-related criteria.

Application-level security was the focus of the third investigation. The use of protocols to ensure the authenticity and confidentiality of interactions with protected servers in a web-based environment was examined. Issues associated with the integrity of downloaded code and the confidentiality of passwords were examined.

This research supported a broad effort in the area of computer security education. Work included the development or improvement of intermediate and advanced graduate courses in computer security, the dissemination of course materials using both traditional and electronic media, an invited lecture series on computer security topics. As part of the effort, a workshop on education in computer security education was initiated.

PUBLICATIONS:

Irvine, C.E., Warren, D. F., and Stemp, R., "Teaching Computer Security at a Department of Defense University," Naval Postgraduate School Technical Report, NPS-CS-97-002, April 1997.

Irvine, C.E., Warren, D. F., and Stemp, R., "The NPS CISR Graduate Program in INFOSEC Education: Six Years of Experience," *Proceedings of the 20th National Information Systems Security Conference*, Baltimore, MD, pp. 22-30, October 1997.

Irvine, C.E., "Challenges in Computer Security Education," *IEEE Software*, Vol. 14, No. 5, pp.110-111, 1997.

CONFERENCE PRESENTATIONS:

Irvine, C. E., "An Approach to Graduate Education in Computer Security," First ACM Workshop on Education in Computer Security, Monterey, CA, January 1997.

Irvine, C. E., "Internet Security? Only If You Know How," 10th Annual Federal Information System's Security Educators' Association Conference, Gaithersburg, MD, March 1997.

Irvine, C.E., Warren, D. F., and Stemp, R., "The NPS CISR Graduate Program in INFOSEC Education: Six Years of Experience," 20th National Information Systems Security Conference, Baltimore, MD, October 1997.

THESES DIRECTED:

Downey, J. P. and Robb, D. A., "Design of a High Assurance Multilevel Security Mail Server (HAMMS)," Master's Thesis, Naval Postgraduate School, September 1997.

Harris, R. and Buettner, R., "A Comparative Analysis of Commercial Off-the-Shelf Software for Use in Transmitting Sensitive but Unclassified Data," Master's Thesis, Naval Postgraduate School, September 1997.

Weldon, S. G., "Protocols for Secure Client-Server Applications in the Joint Maritime Command Information System," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Network Security, High Assurance Systems

CENTER FOR INFORMATION SYSTEMS SECURITY (INFOSEC) STUDIES AND RESEARCH
Cynthia E. Irvine, Assistant Professor
Department of Computer Science
Sponsor: National Security Agency

OBJECTIVE: The objective of this research is to provide ongoing support to the development of the NPS Center for Information Systems Security (INFOSEC) Studies and Research at NPS Center for Information Security Research (CISR). The Center will serve DoN, DoD, and U.S. Government needs in INFOSEC through: curriculum development, a trusted systems laboratory, faculty development, a visiting professor program, an invited lecture series, academic outreach, and work with graduates. The intent of the program is to develop a comprehensive approach to INFOSEC education and research that better serves the needs of the warfighter and the intelligence community.

SUMMARY: In support of research, this project continued an effort to build a high assurance multilevel secure local area network (LAN). A controller board for use at untrusted client workstations has been identified. It will provide trusted path, workstation initialization, and object reuse facilities. The board, currently used for media encryption to workstation disk drives, will be modified to provide the trusted computing base extension functionality identified as necessary for a multi-level secure LAN.

This research also supported the initiation of an effort to explore the use of split address space technology to provide high assurance support of threads in an environment intended to create partially ordered privilege domains. This base will be used to support a system for the dynamic adaptation and retooling of software.

PUBLICATIONS:

Chin, S-K., Irvine, C.E., and Frinke, D., "An Information Security Education Initiative for Engineering and Computer Science," Naval Postgraduate School Technical Report, NPS-CS-97-003, Naval Postgraduate School, December 1997.

Irvine, C.E., "Naval Postgraduate School Center for INFOSEC Studies and Research: Teaching the Science of Computer Security," *Proceedings MILCOM '97*, Monterey, CA, November 1997.

CONFERENCE PRESENTATION:

Irvine, C.E., "Naval Postgraduate School Center for INFOSEC Studies and Research: Teaching the Science of Computer Security," MILCOM '97, Monterey, CA, November 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer Security, Network Security, High Assurance Systems, INFOSEC, Education, Research

A ROBOTIC SYSTEM FOR UNEXPLODED ORDNANCE (UXO)/MINE DETECTION
Yutaka Kanayama, Professor
Department of Computer Science
Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis

OBJECTIVES: The objective of this proposal is to support the activities of the interdisciplinary multi-faculty group project, "A Semi-Autonomous Land/Aerial Robotics System for UXO/Mine Detection and Clearing," More specifically, this proposal is for supporting some of the equipment and travel expense to run the research.

SUMMARY: The robotic vehicle "Shepherd" was constructed in September 1996. This vehicle has a unique feature of having the three degrees of freedom in motion as opposed to most wheeled-land vehicles. In this year, the first attempt of developing the real-time operating system for Shepherd was planned and was successfully completed. As a result, a live videotape demo of several complex operations was taken. This project was successfully executed by Professor Kanayama

and Professor Yun, Department of Electrical and Computer Engineering, and three master's students from the Departments of Computer Science and Physics. The software development steps consist of: (1) developing a small operating kernel, (2) developing a basic set of motor control and encoder reading, and (3) developing a set of high level motion behaviors. These projects were completely successful by September 1997.

PUBLICATIONS:

Kanayama, Y. and Hartman, B., "Smooth Local Path Planning for Autonomous Vehicles," *International Journal of Robotics Research*, Vol. 16, No. 3, pp. 263-284, 1997.

Kanayama, Y. and Fahroo, F., "A New Line Tracking Method for Nonholonomic Vehicles," *International Journal of Robotics Research*, 1997.

Kanayama, Y. and Fahroo, F., "A New Line Tracking Method for Nonholonomic Vehicles," *Proceedings of the IEEE International Conference on Robotics and Automation*, Albuquerque, NM, pp. 2908-2913, 21-27 April 1997.

Kanayama, Y., "Rotary Vehicle That Moves with Three Degrees of Freedom," *Proceedings of the International Conference on Advanced Robotics*, Monterey, CA, pp. 713-718, 7-9 July, 1997.

Kanayama, Y. and Fahroo, F., "A Circle Tracking Method for Nonholonomic Vehicles," *Proceedings of the Fifth IFAC Symposium on Robot Control*, Nantes, France, pp. 551-558,3-5 September, 1997

Morsy, K.A. and Kanayama, Y., "A New Straight Edge Detection Algorithm Using Direction-Controlled Edge Tracking and Random Hitting," *Proceedings of the IEEE International Symposium on Computational Intelligence in Robotics and Automation*, Monterey, CA, pp. 398-405, 10-11 July 1997.

Yoneda, K., Kanayama, Y., and Suzuki, K., "Gait and Foot Trajectory Planning for Versatile Motions of a Six Legged Robot," *Journal of Robotic Systems*, Vol.14, No. 2, pp. 121-133, 1997.

THESES DIRECTED:

Mays, E. and Reid, F., "Motion Control of a Rotary Vehicle," Master's Thesis, Naval Postgraduate School, September 1997.

Morsy, K., "An Efficient Model-Based Image Understanding Method for an Autonomous Vehicle," Ph.D. Dissertation, Naval Postgraduate School, September 1997.

PATENT APPLICATION:

Kanayama, Y., "Continuous Curvature Motion Control of Autonomous Vehicles," being prepared.

DoD TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Ground Vehicles

KEYWORDS: Autonomous Vehicle, Mine/UXO Detection and Clearing, Omni-Directional Vehicle, Motion Control, Human Interface

PROJECT SUMMARIES

MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN)
Taylor Kidd, Associate Professor
Debra Hensgen, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: A research and design effort directed at solving the fundamental problems associated with and creating a distributed metacomputer.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Heterogeneous, Distributed Computing, Data Staging, Metacomputing

RE-ARCHITECTING DEFENSE TECHNICAL INFORMATION CENTER
Ted Lewis, Professor
Department of Computer Science
Sponsor: Defense Technical Information Center

OBJECTIVE: To redesign the computing infrastructure for the Defense Technical Information Center at Ft. Belvoir, VA.

SUMMARY: Interview, analyze, specify, and design the next-generation systems architecture for the DoD's premier technical report center. All reports (and NPS theses) go to DTIC where they are scanned into a computer database for indexing and cataloging. The problem is, the web has changed how this system should work. The recommendations will be used to re-architect DTIC into a web-based digital library system of the future.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Digital Library, Text Retrieval, Information Retrieval, Data Warehousing, Data Mining, Workflow Management

ARTIFICIAL INTELLIGENCE (AI) SYSTEM FOR DETECTION AND CLASSIFICATION OF UNEXPLODED ORDNANCE (UXO)/LAND MINES
Nelson Ludlow, Major, USAF
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This project supports an artificially-intelligent robot system to detect and classify UXO and land mines. This is an interdisciplinary multi-faculty group project. Neural networks and blackboard architectures will be developed to first detect UXO and land mines, and then determine which UXO/land mine the system is looking at, based upon the sensor data of magnetometers and visual camera. Several existing systems can detect if something metallic is on the ground, however, no one yet has a working system that can classify what the robot is looking at.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface

KEYWORDS: Artificial Intelligence, Neural Networks, Blackboard Architecture, UXO, Land Mines

APPLICATIONS AND FUTURE DIRECTIONS OF THE INTERNET
G.M. Lundy, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The internet is rapidly changing the way of doing business for the military, industry, and also personal communications all over the world. Of interest is the future directions the internet will take, how it may be used to the advantage of the military, as well as in other ways and in problems it may have; for example, security and overloading of the communications channels. A student is also exploring the possibilities. The main objectives are to investigate: (1) future directions of the internet; (2) applications, especially for the military; and (3) problems which have or are expected to occur.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Internet, Communications

GUIDELINES AND SOFTWARE ARCHITECTURE FOR RISK ASSESSMENT IN SOFTWARE REUSE
Luqi, Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This project will mitigate risks in software reuse by developing guidelines for risk assessment and develop a software architecture for performing the software risk assessment. Risks in software reuse include unreliable components, expensive searching, lack of compatibility, and brittleness. These risks must be managed to avoid cost/schedule overruns and inadequate software systems. Areas to be considered are user interface, decision support, and techniques for managing and retrieving the reusable software components with efficient algorithms in developing and validating the guidelines and software architecture.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software Reuse, Risk Assessment, Software Architecture

FORMAL MODELS USED FOR AUTOMATION IN SOFTWARE DEVELOPMENT
Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Office

OBJECTIVE: The objectives of the proposed research are the design of an integrated set of formal models and methods for automating a wide range of design and development tasks for real-time systems.

SUMMARY: The project focused on automation of design activities that appear in an evolutionary prototyping approach to software development. This research used a set of state-of-the-art formal methods in software engineering to construct a cohesive set of formal models. These models were used to create and to unify automated processes for computer-aided prototyping.

Mathematical models for implementing a set of automated and integrated software tools were developed. This research combines very-high-level specification abstractions and concepts with formal real-time models, automated management of software design data and human resources, transformations, change merging, and automated retrieval of reusable software components to provide automated methods for generating real-time programs and for coordinating teams of developers.

PUBLICATIONS:

Berzins, V., Ibrahim, O., and Luqi, "A Requirements Evolution Model for Computer-Aided Prototyping," *Proceedings of the 9th International Conference on Software Engineering and Knowledge Engineering,* Madrid, Spain, pp. 38-47, 17-20 June 1997.

Leonard, T., Berzins, V., Luqi, and Holden, M., "Gathering Requirements from Remote Users," *Proceedings 9th International Conference on Tools with Artificial Intelligence,* Newport Beach, CA, pp. 462-471, 3-8 November 1997.

Luqi, and Goguen, J. "Formal Methods: Promises and Problems," *IEEE Software,* Vol. 14, No. 1, pp. 73-85, January 1997.

Luqi, and Berzins, V., "Engineering Automation for Computer-Based Systems," *Proceedings of the 1997 Workshop on Virtual Universities,* Newport Beach, CA, 4 November 1997.

Luqi, "Formal Models and Prototyping," *Proceedings of the 1997 ARO Workshop on Requirements Targeting Software and System Engineering - Towards a Scientific Basis,* Munich, Germany, 12-14 October 1997.

CONFERENCE PRESENTATIONS:

Luqi, "Formal Models and Prototyping," ARO Workshop on Requirements Targeting Software and Systems Engineering, Bernried, Germany, 13 October 1997.

Luqi, "Engineering Automation for Computer Based-Systems," Workshop on Virtual Universities, Newport Beach, CA, 4 November 1997.

THESES DIRECTED:

Bailey, F. and Robbins, C., "Real-Time, Remotely Controlled, Unmanned, Surface Combatant (RTRCUSC) Using the Internet," Master's Thesis, Naval Postgraduate School, September 1997.

Bell, A., "Documentation for Computer-Aided Prototyping System (CAPS) User Interface and Graphic Editor," Master's Thesis, Naval Postgraduate School, March 1997.

Coleman, M., "CHANNEL CAT: A Tactical Link Analysis Tool," Master's Thesis, Naval Postgraduate School, September 1997.

Dabose, M., "Autonomous Agents for Digital Network Maximization," Master's Thesis, Naval Postgraduate School, September 1997.

Evans, J., "Project Scheduling Tool," Master's Thesis, Naval Postgraduate School, September 1997.

Garingo, G., "Java Based Data Connectivity," Master's Thesis, Naval Postgraduate School, September 1997

Herman, J., "Improving Syntactic Matching for Multi-Level Filtering," Master's Thesis, Naval Postgraduate School, September 1997.

Howell, M., "Analysis of a 3-Tier Distributed Architecture for the Sector Anti-Air Warfare Center," Master's Thesis, Naval Postgraduate School, September 1997.

Keesling, W., "Decomposition Recovery Extension to the Computer-Aided Prototyping System (CAPS) Change-Merge Tool," Master's Thesis, Naval Postgraduate School, September 1997.

Leonard, T., "Front Loaded Accurate Requirements Engineering (FLARE): A Requirements Analysis Concept for the 21st Century," Master's Thesis, Naval Postgraduate School, September 1997.

Mock, C., "A Syntax Directed Editor for the Computer-Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, September 1997.

Plutchak, B., "The Design of an Interface Editor for the Computer-Aided Prototyping System," Master's Thesis, Naval Postgraduate School, September 1997.

Ray, W., "Automatic Layout Techniques for the Graphical Editor in the Computer Aided Prototyping System," Master's Thesis, Naval Postgraduate School, September 1997.

Rusin, D., "Application of the Rapid Computer Aided Prototyping System (CAPS) in the Development of a Sudden Infant Death Syndrome (SIDS) Monitor," Master's Thesis, Naval Postgraduate School, June 1997.

Yetkin, E. and Sotero, S., "Re-Engineering Portability of Computer Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computer-Aided Prototyping System (CAPS), Software Engineering

COMPUTER-AIDED PROTOTYPING APPLIED TO ARMY TACTICAL MISSILE SYSTEM (ATACMS)
Luqi, Professor
Department of Computer Science
Sponsor: U.S. Army Research Laboratory

OBJECTIVE: The Computer-Aided Prototyping System (CAPS) is an integrated software development environment aimed at rapidly prototyping hard real-time systems. The objective of the proposed project is to use CAPS to evaluate and refine the requirements for the ATACMS. This will improve the quality of the product and its interoperability across different branches of DoD.

SUMMARY: The project has established the feasibility of using CAPS for modeling and simulation to evaluate integration of large-scale systems like ATACMS. The top level model of the ATACMS has been completed and evaluated. The top level prototype has more than 5000 lines of code. CAPS is able, either indirectly or through derived attributes, to represent requirements. The automatic scheduling, graphical translation and code generation are essentially error-free. CAPS can support more detailed modeling to assess and remove risks to data interoperability across the diverse links planned for ATACMS.

THESIS DIRECTED:

Angrisani, D. and Whitbeck, G., "Software System Requirements for the Army Tactical Missile System," Master's Thesis, Naval Postgraduate School, September 1996.

TECHNICAL REPORT:

Luqi, "Using CAPS for ATACMS," Project Report, Army Research Laboratory, 1997.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Computer-Aided Prototyping System (CAPS), Army Tactical Missile System (ATACMS)

COMPUTER-AIDED PROTOTYPING OF REAL-TIME SYSTEMS
Luqi, Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: This research is aimed at computer-aided prototyping tools or designing real-time software systems. The main research problems are developing abstract models and implementation techniques based on formalized specifications.

SUMMARY: Many subjects were worked on related to software automation: program generation from specifications, real-time scheduling, computer-aided reuse, design databases, software evolution, the coupling between graphical interfaces and partial automatic inference of software designs, and the first prototyping language for real-time systems (PSDL - Prototype System Description Language) based on formal semantics. The project received donations of hardware and software from many industrial organizations to build the lab, and has produced 20 journal papers, 51 conference papers, chapters in seven books, seven Ph.D dissertations, and 49 Master's theses from FY91 through FY97.

PUBLICATIONS:

Berzins, V., Ibrahim, O., and Luqi, "A Requirements Evolution Model for Computer Aided Prototyping," *Proceedings of the 9th International Conference on Software Engineering and Knowledge Engineering*, Madrid, Spain, pp. 38-47, 17-20 June 1997.

Leonard, T., Berzins, V., Luqi, and Holden, M., "Gathering Requirements from Remote Users," *Proceedings 9th International Conference on Tools with Artificial Intelligence*, Newport Beach, CA, pp. 462-471, 3-8 November 1997.

Luqi and Goguen, J., "Formal Methods: Promises and Problems," *IEEE Software*, Vol. 14, No. 1, pp. 73-85, January 1997.

Luqi, and Berzins, V., "Engineering Automation for Computer Based Systems," *Proceedings of the 1997 Workshop on Virtual Universities*, Newport Beach, CA, 4 November 1997.

Luqi, "Formal Models and Prototyping," *Proceedings of the 1997 ARO Workshop on Requirements Targeting Software and System Engineering - Towards a Scientific Basis*, Munich, Germany, 12-14 October 1997.

CONFERENCE PRESENTATIONS:

Luqi, "Formal Models and Prototyping," ARO Workshop on Requirements Targeting Software and Systems Engineering, Bernried, Germany, 13 October 1997.

Luqi, "Engineering Automation for Computer-Based Systems," Workshop on Virtual Universities, Newport Beach, CA, 4 November 1997.

THESES DIRECTED:

Bailey, F. and Robbins, C., "Real-Time, Remotely Controlled, Unmanned, Surface Combatant (RTRCUSC) Using the Internet," Master's Thesis, Naval Postgraduate School, September 1997.

Bell, A., "Documentation for Computer-Aided Prototyping System (CAPS) User Interface and Graphic Editor," Master's Thesis, Naval Postgraduate School, March 1997.

PROJECT SUMMARIES

Coleman, M., "CHANNEL CAT: A Tactical Link Analysis Tool," Master's Thesis, Naval Postgraduate School, September 1997

Dabose, M., "Autonomous Agents for Digital Network Maximization," Master's Thesis, Naval Postgraduate School, September 1997.

Evans, J., "Project Scheduling Tool," Master's Thesis, Naval Postgraduate School, September 1997.

Garingo, G., "Java Based Data Connectivity," Master's Thesis, Naval Postgraduate School, September 1997

Herman, J., "Improving Syntactic Matching for Multi-Level Filtering," Master's Thesis, Naval Postgraduate School, September 1997.

Howell, M., "Analysis of a 3-Tier Distributed Architecture for the Sector Anti-Air Warfare Center," Master's Thesis, Naval Postgraduate School, September 1997.

Keesling, W., "Decomposition Recovery Extension to the Computer-Aided Prototyping System (CAPS) Change-Merge Tool," Master's Thesis, Naval Postgraduate School, September 1997.

Leonard, T., "Front Loaded Accurate Requirements Engineering (FLARE): A Requirements Analysis Concept for the 21st Century," Master's Thesis, Naval Postgraduate School, September 1997.

Mock, C., "A Syntax Directed Editor for the Computer Aided Prototyping System (CAPS)," Master's Thesis, September 1997.

Plutchak, B., "The Design of an Interface Editor for the Computer-Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, September 1997.

Ray, W., "Automatic Layout Techniques for the Graphical Editor in the Computer-Aided Prototyping System (CAPS)," Master's Thesis, Naval Postgraduate School, September 1997.

Rusin, D., "Application of the Rapid Computer-Aided Prototyping System (CAPS) in the Development of a Sudden Infant Death Syndrome (SIDS) Monitor," Master's Thesis, Naval Postgraduate School, June 1997.

Yetkin, E. and Sotero, S., "Re-Engineering Portability of Computer Aided Prototyping System," Master's Thesis, Naval Postgraduate School, March 1997.

TECHNICAL REPORTS:

Luqi, "Computer Aided Prototyping of Real-Time Systems," Final Report, CCR-9058453, National Science Foundation, December 1997.

OTHER: CAPS Software

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Prototype System Description Language (PSDL), Real-Time Scheduling, Computer-Aided Reuse, Design Databases, Software Evolution

AUTONOMOUS AGENTS APPLICABLE TO THE REAL-TIME RETARGETING PROGRAM
Luqi, Professor
Department of Computer Science
Sponsor: Space and Naval Warfare Systems Center-San Diego

OBJECTIVE: The objective of the project is to enable retargeting in real-time as new threats emerge, while utilizing existing tactical communications links. The proposed approach is to use autonomous software agents to manage network resources to increase effective throughput, by a combination of differential transmission techniques, data compression, and global network load balancing.

SUMMARY: A key issue for real-time retargeting is transmitting the required information to the systems that must respond via existing tactical communications links within tight timing requirements. Current tactical networks have limited speed and are already straining their transmission capacity. Thus real-time retargeting in this environment requires improving bandwidth utilization with the goal of optimizing the actual information transmitted.

Many current network strategies, both commercial and tactical, rely on repeated broadcast of standardized messages. As a result, much available bandwidth is wasted on the repeated transmission of redundant information. The approach taken to maximize specific network node throughput on a digital network is a three-layer paradigm, managed by an embedded autonomous software agent located at each network node. The first layer consists of a network specific strategy for reducing the message content. The second layer is a frame-by-frame analysis of the reduced message content to determine the best compression method to be applied to the information itself (MPEG, etc.). The third layer is a packaging strategy to maximize the packaging of each specific network packet.

The first phase of a proof-of-concept prototype has been implemented. Initial results, via a network simulation, have demonstrated a quantitative 300% plus increase in effective information throughput capability, utilizing the same physical bandwidth. Since this approach is an embedded technique, existing network hardware, software, and standards remain uneffected. A side benefit witnessed is increased network responsiveness due to increased information flow in a timely manner. In terms of processing time required, the cost is more than compensated by increased information transfer capacity that can be used to realize future requirements for real-time retargeting.

THESIS DIRECTED:

Dabose, M., "Autonomous Agents for Digital Network Maximization," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Autonomous Agents, Networks, Capacity Optimization

AUTONOMOUS AGENTS FOR DIGITAL NETWORK MAXIMIZATION
Luqi, Professor
Department of Computer Science
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this effort is to make more effective use of the limited bandwidth available on DoD Links. The proposed approach is to use autonomous software agents to manage network resources to increase effective throughput, by a combination of differential transmission techniques, data compression, and global network load balancing. An architecture for such agents will be described and assessed.

SUMMARY: An important problem arising from the increased sharing of information across networks is bandwidth constraint. The limitations of communications channels in the transmission of voluminous information is the singular bottleneck dictating processing capability and robustness of current and future distributed systems. Bandwidth utilization with the goal of optimizing the actual information transmitted, has to date, been ignored. Many of the current network strategies,

both commercial and tactical, rely on the repeated broadcast of a standardized message. As a result, much available bandwidth is wasted on the repeated transmission of redundant information. The specific approach taken to maximize specific network node throughput on a digital network is a three-layer paradigm, managed by an embedded autonomous software agent located at each network node.

The first layer consists of a network specific strategy for reducing the message content. The second layer is a frame-by-frame analysis of the reduced message content to determine the best compression method to be applied to the information itself (MPEG, etc.). Finally, a packaging strategy to maximize the packaging of each specific network packet. The first phase of a proof-of-concept prototype has been implemented. Initial results, via a network simulation, have demonstrated a quantitative 300% plus increase in effective information throughput capability, utilizing the same bandwidth. Since this approach is an embedded technique, existing network hardware, software, and standards remain uneffected. A side benefit witnessed is increased network responsiveness due to increased information flow in a timely manner. In terms of processing time required, the cost is more than compensated for by increased network efficiency. The net result is a more efficient and responsive network capability.

THESIS DIRECTED:

Dabose, M., "Autonomous Agents for Digital Network Maximization," Master's Thesis, Naval Postgraduate School, September 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Autonomous Agents, Networks, Capacity Automization

AN EXPERIMENTAL STUDY OF SOFTWARE ARCHITECTURES AND SOFTWARE REUSE FOR CONTROL OF UNMANNED UNDERWATER VEHICLES
R.B. McGhee, Professor
Department of Computer Science
A.J. Healey, Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate alternative software architectures for control of unmanned underwater vehicles, and to find effective means for archiving and retrieving software modules used to implement such software systems. The research was conducted in cooperation with the Monterey Bay Aquarium Research Institute (MBARI) and INRIA, a French Government Research Institute.

SUMMARY: This was a three-year project which began in 1994 and terminated 30 June 1997. During calendar year 1997, much of the work was focused on further development of the "Rational Behavior Model" (RBM) software architecture, and its testing, using both the physical Naval Postgraduate School *Phoenix* autonomous underwater vehicle (AUV) and its real-time simulation model. This work was successful. A small AUV navigation system (SANS) based on a combination of a low cost strapped down inertial measurement unit (IMU) and a miniaturized global positioning system (GPS) receiver was successfully tested. An advanced "point and click" mission planning software expert system was developed which allows mission specialists to automatically generate mission control software without any manual coding. The attainment of these results meets the primary objectives of the original project plan and provides a basis for the development of more advanced AUVs specifically configured for various shallow-water tasks such as mine hunting, coastal environmental monitoring, etc.

PUBLICATION:

Davis, D.T., Brutzman, D.P., Leonard, B.J., and McGhee, R.B., "Operational Mission Planning and Mission Control for the *Phoenix* Autonomous Underwater Vehicle," accepted for publication in *IEEE Journal of Oceanic Engineering,* 1998.

THESES DIRECTED:

Knapp, R. G., "Calibration and Evaluation of Waterspeed Indicator and Compass for the Small AUV Navigation Filter," Master's Thesis, Naval Postgraduate School, December 1997.

Roberts, R.L., "Implementation and Evaluation of an Integrated Self-Contained GPS/INS Shallow-Water AUV Navigation System (SANS)," Master's Thesis, Naval Postgraduate School, March 1997.

Thorne, R.L., "Asynchronous Data Fusion for AUV Navigation Using Extended Kalman Filtering," Master's Thesis, Naval Postgraduate School, March 1997.

DoD KEY TECHNOLOGY AREA: Other (Military Robotics)

KEYWORDS: Robotics, Mine Countermeasures, Autonomous Underwater Vehicles (AUV)

NPSNET: JANUS SOLDIER STATION-PHASE 1 AND 2
David Pratt, Associate Professor
Department of Computer Science
Sponsor: U.S. Army Training and Doctrine Analysis Command

OBJECTIVE: The graphics ad video laboratory of the Department of Computer Science at NPS is currently conducting research in the connection of the JANUS combat model to the distributed interactive simulation (DIS) environment. The focus of this project is the integration of the JANUS combat model routines into NPSNET to produce a single integrated system. This project will leverage off existing and supporting JANUS research efforts.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Combat Models, Graphics Artificial Intelligence, Computer Networks

TECHNICAL SUPPORT FOR THE JOINT SIMULATION SYSTEM (JSIMS) JOINT PROGRAM
David Pratt, Associate Professor
Department of Computer Science
Sponsor: Joint Simulation System Joint Project Office

OBJECTIVE: To act as the JSIMS Technical Director.

SUMMARY: As the JSIMS System continues to grow, it has become apparent that there is a need for a Technical Director who acts as an advisor to the project management on technical issues. The principal investigator was selected as such an individual. In this capacity, Dr. Pratt represented the program on several managerial and technical panels and forums. He was also instrumental in providing technical guidance and helping to set up the program.

PUBLICATIONS:

Powell, E. and Pratt, D., "The Joint Simulation System Architecture: A Foundation for Future Training Systems," *Proceedings of the 19th Interservice Industry Training Systems and Education Conference*, Orlando, FL, December 1997.

Pratt, D. and Beasley, Drew W., "Issues In Modeling And Simulation: Policies And Technologies," *Proceedings of the 1997 Winter Simulation Conference*, Atlanta, GA, December 1997.

Pratt, D., Peabody, C., and Liby, G., "The Joint Simulation System Software Development Process," *Proceedings of the Ninth Software Technology Conference*, Salt Lake City, UT, April 1997.

DoD TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel, and Training

KEYWORDS: Combat Models, Graphics, Synthetic Environments, Artificial Intelligence, Computer Networks

ARTIFICIAL INTELLIGENCE FOR TERRAIN-DATABASE INTEGRATION
Neil C. Rowe, Associate Professor
Department of Computer Science
Sponsor: U.S. Army Training and Doctrine Analysis Command

OBJECTIVE: To investigate, using ideas from artificial intelligence, how to simplify the integration of diverse terrain databases.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Terrain Databases, Data Structures, Software Integration

RESOLUTION OF DATA-SOURCE INCOMPATIBILITIES IN TERRAIN DATABASES
Neil C. Rowe, Associate Professor
Department of Computer Science
Sponsor: Information Management Support Center

OBJECTIVE: To write software to intelligently resolve incompatibilities between different terrain databases.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Terrain Databases, Data Structures, Software Integration

AUTOMATIC INDEXING OF PICTURES ON INTERNET PAGES
Neil C. Rowe, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: To build a prototype system that finds the photographs on Internet/World Wide Web pages, finds their captions, and indexes them.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interfaces

KEYWORDS: Captions, Photographs, Parsing, Artificial Intelligence

DEVELOPMENT OF THE GEOLOCATION WORKBENCH
Timothy J. Shimeall, Associate Professor
Department of Computer Science
Herschel H. Loomis, Professor
Department of Electrical and Computer Engineering
Sponsor: Navy Engineering Logistics Office

OBJECTIVE: This proposal will support the development of a facility to develop and analyze geolocation algorithms in a project-nonspecific manner. The outcome of this two-year project will support interoperability between existing signal data collection systems and increase the ability to adapt existing data analysis systems to new use.

DoD KEY TECHNOLOGY AREA: Command, Control, and Comunications

KEYWORDS: Geolocation Algorithms, Signal Processing

REFINEMENT OF SOFTWARE SAFETY ANALYSIS TOOLS
Timothy J. Shimeall, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: This research will refine existing safety analysis tools, improving the reliability and general functionality of the tools. These tools are currently of interest to a number of Navy and DoD projects.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Safety Analysis Tools

ONLINE POLYMORPHIC TYPE INFERENCE IN IMPERATIVE LANGUAGES
Dennis Volpano, Associate Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: This work is part of a continuing project in which the primary objective is to investigate new type theories for imperative programming languages.

SUMMARY: This project is a joint effort with Geoffrey Smith at the Florida International University (FIU). The project ended at FIU in 1996, but NPS was granted a one-year extension in October 1996 to complete the remaining work originally proposed. During the first two years of the project, an ML-style polymorphic type system was designed for a dialect of C, called Polymorphic C. The type system allows these operations in their full generality, so that programmers need not give up the flexibility of C to gain the benefits of ML-style polymorphism and rigorous type reconstruction. A type soundness theorem was proved that gives a rigorous and useful characterization of well-typed Polymorphic C programs in terms of what can go wrong when they are evaluated.

This theorem, called a progress theorem, could not be proved with a natural semantics since such a semantics cannot cope with partial executions and failure. In 1996, Smith introduced a new style of semantics based on transitions between partial derivation trees. The semantics was formulated as a formal system of inference rules by Volpano in 1997. The formal system is called a Natural Transition Semantics.

PUBLICATION:

Smith, G. and Volpano, D., "A Sound Polymorphic Type System for a Dialect of C," to appear in *Science of Computer Programming*, Vol. 32, Nos. 2-3, 1998.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Programming Languages, Semantics, Static Analyses

AN ENVIRONMENT FOR DEVELOPING SECURE SOFTWARE
Dennis Volpano, Associate Professor
Cynthia Irvine, Assistant Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: This work is part of a continuing project aimed at developing new techniques for statically analyzing code, that is targeted for remote execution, and for secure flow violations. The algorithm will attempt to construct a proof, for a given program, in a sound flow logic, thereby establishing the program as secure. The algorithm will permit remote code, written in Web-based languages like Java and JavaScript, to be analyzed prior to execution in order to determine whether it can be executed safely.

SUMMARY: In 1997, Volpano and Smith (Florida International University), completed a decidable secure flow logic for a core imperative language with procedures. The logic is a type system with subtyping that arises due to treating upward information flow. Interesting subtype relationships exist. For instance, the subtype relation is covariant in expression types, but contravariant in command (statement) types. A type inference algorithm was developed for the logic. Type inference in this setting is interesting due to procedures which have principal types that effectively document how these procedures can be called securely in some context. The algorithm was proved sound and completed relative to the logic and prototyped by Smith in Scheme.

PUBLICATIONS:

Volpano, D. and Irvine, C., "Secure Flow Typing," *Computers and Security*, Vol. 16, No. 2, pp. 137-144, 1997.

Volpano, D. and Smith, G., "A Type-Based Approach to Program Security," *Proceedings of the 7th International Joint Conference on the Theory and Practice of Software Development*, Lecture Notes in Computer Science 1214, pp. 607-621, 1997.

Volpano, D. and Smith, G., "Language Issues in Mobile Program Security," accepted for publication in a special issue of Lecture Notes in *Computer Science on Mobile Agents and Security*.

CONFERENCE PRESENTATIONS:

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Volpano, D., "Pursuing Provable Privacy in Programs," DARPA Principal Investigator's Meeting, Lake Tahoe, CA, August 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Secure Information Flow, Remote Evaluation

TYPE SYSTEMS FOR SECURE REMOTE EVALUATION
Dennis Volpano, Associate Professor
Department of Computer Science
Sponsor: National Science Foundation

OBJECTIVE: This is a joint project with Geoffrey Smith at the Florida International University (FIU). The work is part of a continuing project aimed at investigating the role of programming language design and type systems in ensuring the security of servers in remote evaluation systems. The long-term objective is to identify how languages should be designed to guarantee provable confinement properties for all programs expressed in these languages.

SUMMARY: We developed an extension of a secure-flow type system that treats two easy ways that sequential programs can leak private information, specifically, nontermination and exceptions. In a purely synchronous programming language, either can be used to leak data covertly. We discovered that these two ways could be prohibited in a type system by typing the continuations of partial-recursive constructs and partial operations as functions over public data only. The system can also be modified to rule out all covert timing channels in an asynchronous language by typing continuations of branch statements in the same way. The resulting system is more restrictive and it is not clear whether it is still useful in practice.

PUBLICATION:

Volpano, D. and Smith, G., "Eliminating Covert Flows with Minimum Typings," *Proceedings of the 10th IEEE Computer Security Foundations Workshop*, pp. 156-168.

CONFERENCE PRESENTATIONS:

Volpano, D., "Eliminating Covert Flows with Minimum Typings," 10th IEEE Computer Security Foundations Workshop, Rockport, MA, June 1997.

Volpano, D., "Secure Information Flow in a Multi-Threaded Imperative Language," Workshop on Security and Languages, DEC Systems Research Center, Palo Alto, CA, October 1997.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Type Systems, Remote Evaluation, Security

WORKSHOP ON PROVABLY-SECURE PROGRAMMING
Dennis Volpano, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The aim of the workshop was to explore the relationship between the design of programming languages and security models.

SUMMARY: The workshop was held in Monterey, CA, 26-28 March 1997. Its official title is the "1997 Foundations for Secure Mobile Code Workshop." The 25 attendees from industry and academia were asked to prepare position statements which were provided in advance to all attendees on the web. Statements addressed basically two types of security problems: protecting servers from mobile code and protecting mobile code from malicious servers. The latter problem was viewed as more intractable, given the need for mobile code to rely on an execution platform of some sort. Participants presented their positions and discussion followed. All presentations and discussions were recorded for future reference, however, a final report was not written.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORD: Security

DESIGN AND IMPLEMENTATION OF AIRPAC FINANCIAL ANALYSIS TOOL II (AFAST)
Thomas Wu, Associate Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: In 1994, VADM Spane (Commander, Naval Air Forces Pacific) requested a study to assess the financial management capabilities of the AIRPAC command. One of the many recommendations provided by the study is the development of a financial information system capable of providing timely and consistent financial information for the AIRPAC. The AFAST system was built as a result. However, the system has met the original goals only partially. The system has many limitations, which must be rectified in order for the system to be usable in highly data-intensive, client/server environment. Without upgrading the current system, growing needs of the AIRPAC cannot be met. The proposal is to redesign and implement an improved version of the AFAST.

DoD KEY TECHNOLGY AREA: Other (Financial Management)

KEYWORDS: AFAST, Financial Management

NETWORK SUPPORT FOR MULTIMEDIA APPLICATIONS
Goeffrey G. Xie, Assistant Professor
Department of Computer Science
Sponsor: Naval Postgraduate School

OBJECTIVE: The goal of the research is to design networks that guarantee application-level quality of services (QoS) to multimedia applications.

SUMMARY: The three active projects are: (1) Design and implementation of SAAM: a novel network management system for support of integrated services in the Next Generation Internet (NGI). The research has identified the stringent requirements of integrated services and developed a server-based and hierarchical active network management architecture; (2) Design and implementation of an application-level guaranteed statistical service for real-time traffic. The research has developed admission control and loss management algorithms for such a service based on a novel traffic model for real-time traffic; and (3)
Design and implementation of a security framework suitable for fast IP routing based on ATM switching. The tradeoff between routing speed and security vulnerability in current IP/ATM proposals was identified.

PUBLICATIONS:

Lam, S.S. and Xie, G.G, "Group Priority Scheduling," *IEEE/ACM Transactions on Networking*, Vol. 5, No. 2, pp. 205-218, April 1997.

Lam, S.S. and Xie, G.G, "Burst Scheduling Networks," *Performance Evaluation*, Vol. 31, pp. 133-157, December 1997.

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Xie, G.G. and Lam, S.S., "Real-time Block Transfer Under a Link Sharing Hierarchy," *Proceedings of the IEEE INFOCOM '97*, Kobe, Japan, April 1997.

Xie, G.G. and Lam S.S., "Admission Control and Loss Management for an Application-Level Statistical Service," *Proceedings of the 1997 IEEE International Conference on Network Protocols*, Atlanta, GA, October 1997.

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Kresho, J., Hensgen, D., Kidd, T., and Xie, G., "Determining the Accuracy Required in Resource Load Prediction to Successfully Support Application Agility," Naval Postgraduate School, NPS-CS-98-001, December 1997.

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DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications

KEYWORDS: Network, Multimedia, Quality-of-Service (QoS), Real-Time, Security

NPSNET-V: RAPIDLY CONFIGURABLE VIRTUAL WORLD
Michael J. Zyda, Professor
Department of Computer Science
Sponsor: National Imagery Mapping Agency

OBJECTIVE: The goal of this proposal is: (1) to architect and begin the implementation of the next generation of NPSNET, NPSNET-V; (2) to continue the work on terrain paging; (3) to continue the work in servicing the external NPSNET visual simulation user community; and (4) to perform leading edge research into terrain database quality and real-time utilization.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: NPSNET, Synthetic Environments, Virtual Environments

RAPIDLY RECONFIGURABLE VIRTUAL ENVIRONMENT NETWORK PROTOCOLS
Michael J. Zyda, Professor
Department of Computer Science
Donald Brutzman, Assistant Professor
Undersea Warfare Academic Group
Sponsor: Office of Naval Research

OBJECTIVE: Research in the area of human interaction in virtual environments is essential as a complimentary effort to NPSNET as well as to the VE research community at large. This proposal will outline plans for a research facility dedicated to this area and the directions to pursue in the coming years.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORD: Research, Engineering, Technology, Synthetic Environments, Distributed Interactive Simulation, Virtual Environments

NPSNET-HUMAN: INSERTING THE HUMAN INTO THE NETWORKED SYNTHETIC ENVIRONMENT
Michael J. Zyda, Professor
David Pratt, Associate Professor
Department of Computer Science
Sponsor: Defense Advanced Research Projects Agency

OBJECTIVE: The Department of Computer Science at NPS has been developing low-cost, networked 3D visual simulation systems for the last eight years. The latest system, NPSNET-IV, utilizes commercial of-the-shelf workstations, terrain databases, and distributed interactive simulation (DIS) networking formats to produce a networked, 3D synthetic environment. This proposal is for an extension of the NPSNET project into the domain of placing humans into the synthetic environment; humans can walk over the ground, and through buildings. These humans will perform a variety of tasks, from dismounted infantry to medical corpsman training. The primary tasks of this project are to examine and utilize technologies useful for human interaction in the synthetic environment, and to provide DIS support for the primary contractor (UPENN). The application domain for this project is the training of medical corpsmen.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Computers, Software, Communications Networking, Environmental Effects, Dismounted Infantry, Medical Corpsman Training

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UTILIZATION OF A VIRTUAL ENVIRONMENT FOR
COMBAT INFORMATION CENTER TRAINING
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Recent fiscal and personnel cutbacks have placed significant restrictions on surface ship training opportunities. As a result, additional methods of training must be established in order to maintain current operational readiness. This thesis research investigates the use of a workstation-based shipboard virtual environment (VE) as complementary training for naval personnel, in particular, in the combat information center (CIC).

The approach taken was to extend the Naval Postgraduate School's Shiphandling Training Simulator (SHIPSIM) and shipboard Virtual Environment Trainer to include a combat information center virtual environment system (CICVET). Using the NPSNET IV framework, the system provides two levels of training; the first reflects the dynamics of real-world warfare theaters with the capability for distant entities to interact, while the second allows for the team training of shipboard personnel, possibly in separate locations, within the same virtual CIC.

To achieve our goal we built a real-time, distributed, interactive shipboard environment for combat information center training. It consists of a three-dimensional CIC model, containing functioning consoles for information display, sensor management, and weapons control.

CROSS MODEL ACCESS IN THE MULTI-LINGUAL,
MULTI-MODEL DATABASE MANAGEMENT SYSTEM
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Relational, hierarchical, network, functional, and object-oriented databases support its corresponding query language, SQL, DL/I, CODASYL-DML, DAPLEX, and OO-DML, respectively. However, each database type may be accessed only by its own language. The goal of M^2DBMS is to provide a heterogeneous environment in which any supported database is accessible by any supported query language. This is known as cross model access capability.

In this thesis, relational to object-oriented database cross model access is successfully implemented for a test database. Data from the object-oriented database EWIROODB is accessed and retrieved, using an SQL query from the relational database EWIROODB. One problem is that the two interfaces (object-oriented and relational) create catalog files with different formation, which makes the cross-model access impossible, initially. In this thesis the relational created catalog file is used, and the cross model access capability is achieved.

The object-oriented catalog file must be identical with the relational one. Therefore, work yet to be done is to write a program that automatically reformats the object-oriented catalog file into an equivalent relational catalog file.

EXPLOSIVE ORDNANCE DISPOSAL ASSOCIATE-
AN EXPERT SYSTEM FOR LANDMINE IDENTIFICATION

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Today there are over 110 million mines scattered across 60 countries, and these mines kill or injure more than 26,000 people annually. In order for deminers to remove these mines, they must be able to quickly and accurately identify them. Existing methods for landmine identification involve tedious searching through reference books.

This thesis presents an expert system for landmine identification, based on the set of thirty Bosnian mines from the MineFacts landmine database. The user is queried about the landmine, and heuristics are applied to the answers which are then used to calculate other information about the mine. This information is then filtered through decision trees to generate a small group of candidates which are displayed with a photo and confidence factor.

The system was modeled and tested using a Microsoft Excel spreadsheet. The system can narrow candidates to within two choices when all queries are correctly answered and to within three candidates when 70% of the queries are correctly answered. The results show that this technique has potential for all types of ordnance identification. A similar system could be implemented to cover all UXO for EOD use and as a reconnaissance tool by non-EOD trained individuals.

INVESTIGATION OF EFFECT OF DIFFERENT RUN-TIME
DISTRIBUTIONS ON SMARTNET PERFORMANCE

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This thesis investigates, using in-line simulation, the effect of non-deterministic runtime distributions on the performance of SmartNet's schedule execution using the Opportunistic Load Balancing (OLB) Algorithm, the Limited Best Assignment (LBA) Algorithm, an $O(mn^2)$ Greedy Algorithm, and an $O(mn)$ Greedy Algorithm. Smart-Net is a framework for scheduling jobs and machines in a heterogeneous computing environment. Its major strength is its use of both current machine loads and predicted job/machine performance when generating schedules. Schedules are built to meet various Quality of Service requirements using the above algorithms among others. We enhanced SmartNet's simulator so that the runtime distributions could be used for experimentation. The distributions were generated using derivations from our study on NAS Benchmarks. Experiments were run for various categories of job/machine heterogeneity to compare the algorithms which account for both load and expected performance (the Greedy algorithms) against OLB and LBA.

For all categories of heterogeneity, the greedy algorithms outperformed the other two algorithms for both truncated Gaussian and exponential distributions. For these same distributions, the $O(mn)$ Greedy algorithm performed as well as the $O(mn^2)$ Greedy algorithm when the heterogeneity of jobs and machines was high.

VIRTUAL ENVIRONMENTS AND WAYFINDING IN THE NATURAL ENVIRONMENT

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The purpose of this study was to determine if a Virtual Environment (VE) model of a natural environment could provide familiarity training transfer. The methods used included aspects from sport orienteering. Fifteen male participants comprising three ability groups participated within three treatment groups. The treatment groups were comprised of a map study, map and VE study, and an actual environment study.

The results indicated that navigational ability had a more pronounced effect on performance then did treatment group. However, among the treatment groups, the intermediate ability group seemed to benefit the most from the VE. Within the VE treatment, the beginner ability group seemed to suffer from excess workload, while the advanced group found the VE treatment only useful for pinpointing the location of the marker.

The results indicate that a properly designed VE can, through training, impart a familiarity with a selected natural environment area, better than map study for all except the most sophisticated land navigators. Further study is needed to examine aspects of the VE, how they need to be represented, and what other refinements or features could be included in such a VE in order to maximize training transfer,

A COMPUTER SIMULATION STUDY OF SINGLE RIGID BODY DYNAMIC MODEL FOR BIPED POSTURAL CONTROL

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Existing kinematics models for humans cannot simulate movement beyond geometric constraints. On the other hand, complex dynamics models are computationally expensive for real-time computer graphics applications in Virtual Environments(VE). To be able to create a more realistic, real-time, and computationally efficient human model, a simple dynamic model needs to be developed.

The approach taken in this thesis was to develop a single rigid body dynamic human model with massless legs. Instead of a Lagrangian model, which complicates the calculations exponentially as the complexity of the system increases, the Newton-Euler method was chosen to derive system differential equations. Linear state feedback was used for postural and gait control. As part of this research, a previous realistic looking human model is further developed.

The major conclusion of this thesis is that a single rigid body dynamic model can be used for simulation of postural control. The simulation results contained in this thesis show that such a modeling technique could be used to cause a detailed kinematic representation of a human figure to move in a smooth and realistic way without resorting to complexity of a multi-link dynamic model.

DOCUMENTATION FOR CAPS USER INTERFACE AND GRAPHIC EDITOR

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The Computer-Aided Prototyping System (CAPS) is an integrated environment, comprised of an integrated set of software tools, aimed at rapidly prototyping hard real-time embedded Systems. The problem with the current CAPS software devel-

opment environment is the absence of a CAPS User's Manual (How to Use ...), which provides CAPS users with step-by-step guidelines on how to use the CAPS tools.

One solution to this problem was solved by designing, developing, and creating on-line documentation for the CAPS User Interface and Graphic Editor Reference Manuals for CAPS Release 1.1. Such an approach provides accessible visual, graphical, and textual step-by-step illustrations for CAPS users when interfacing, interacting, and manipulating, commands and options within the CAPS User Interface subsystem and Graphic Editor tool. In addition, this approach includes a glossary which helps CAPS users to understand the meaning of the difficult or specialized terms used in this environment.

SIMULATION FOR SMARTNET SCHEDULING OF ASYNCHRONOUS TRANSFER MODE VIRTUAL CHANNELS

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Critical to the success of future battlefield commanders is the rapid retrieval of relevant, time sensitive information. Some of this information will be available locally while the remainder is stored in the United States. DARPA's Battlefield Awareness and Data Dissemination (BADD) program attempts to deliver heterogeneous data to the battlefield using the Asynchronous Transfer Mode (ATM) protocol. ATM was originally designed to implement dynamic virtual channels over duplex, high-speed, high capacity, fiber optic cabling. The problem addressed was to determine which algorithm best schedules calls on BADD's ATM network that uses static virtual channels over simplex, error prone, long delay, satellite links. Because the BADD project uses ATM in such an unusual way, and because of the need to determine a schedule for transmissions over the heterogeneous static channels, we modeled BADD using the state-of-the-art network simulation tool, Optimized Network Engineering Tools (OPNET). We determined several modifications that must be made to existing network simulators to allow them to model next-generation networks. Our simulation shows that a greedy algorithm yields a 53% decrease in the overall completion time and a 46% increase in average bit throughput over FIFO scheduling.

A COMPARATIVE ANALYSIS OF COMMERCIAL-OFF-THE-SHELF SOFTWARE FOR USE IN TRANSMITTING SENSITIVE BUT UNCLASSIFIED DATA

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Transmission of electronic data across the national information infrastructure (NII) makes such data vulnerable to interception and modification. Cryptography is the method of choice for protecting data integrity and preventing unauthorized disclosure. An effective and inexpensive method of protecting electronic transfer of sensitive but unclassified (SBU) data across the NII is required. This research develops a procedure to evaluate and compare the performance of Commercial-Off-The-Shelf (COTS) cryptography software products. This procedure is used to recommend cryptography products suitable for use with the Navy's IT-21 initiative. A set of minimum criteria for the software to be evaluated was developed to

verify the general suitability for its use by the Navy in the transfer of SBU information. A search was conducted to determine which COTS products met the minimum criteria. Systematic and detailed evaluation procedures were developed. Products were tested using these procedures and scored using a system adaptable to a variety of potential users. Two products were identified which may be suitable for use with the IT-21 initiative.

CHANNEL CAT: A TACTICAL LINK ANALYSIS TOOL
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The Tri-Service Tactical (TRI-TAC) standards for tactical data links mandate a terminal data rate of 32,000 bits per second. As greater demands for data throughput are placed upon tactical networks, it will become imperative that the design of future client/server architectures do not exceed the capacity of the TRI-TAC networks. This thesis produced an analysis tool, the Channel Capacity Analysis Tool (Channel CAT), designed to provide an automated tool for the analysis of design decisions in developing client-server software.

The analysis tool, built using the Computer Aided Prototyping System (CAPS), provides designers the ability to input TRI-TAC channel parameters and view the results of the simulated channel traffic in graphical format. The size of data, period of transmission, and channel transmission rate can be set by the user, with the results displayed as a percent utilization of the maximum capacity of the channel.

Designed using fielded equipment specifications, the details of the network mechanisms closely simulate the behavior of the actual tactical links. Testing has shown Channel CAT to be stable and accurate. As a result of this effort, Channel CAT provides software engineers an ability to test design decisions for client-server software in a rapid, low-cost manner.

BUILDING A DYNAMIC WEB/DATABASE INTERFACE
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This thesis examines methods for accessing information stored in a relational database from a Web Page. The stateless and connectionless nature of the Web's Hypertext Transport Protocol as well as the open nature of the Internet Protocol pose problems in the areas of database concurrency, security, speed, and performance.

We examined the Common Gateway Interface, Server API, Oracle's Web/database architecture, and the Java Database Connectivity interface in terms of performance and flexibility. Oracle's approach was found to be the most robust and best performing approach currently in use, although the Java Database Connectivity interface has not yet been widely implemented.

Based on our research and experience implementing a prototype, we conclude that Web/database technology is currently only appropriate for read-only type applications such as Decision Support Systems and Information Delivery Systems. The database access methods presently available cannot support more advanced capabilities of client/server type applications including client-side data validation, sophisticated user interfaces, and concurrency among multiple users.

AUTONOMOUS AGENTS FOR DIGITAL NETWORK MAXIMIZATION

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The advent of the computer age has brought about a plenitude of benefits to the human race. Included with these benefits has been the ever-increasing demand to transfer exponentially increasing amounts of information, and the associated problems of information sharing. The focus of this thesis has been to best utilize available digital communications assets in the radio frequency (RF) spectrum to allow sufficient transfer of information providing DoD assets flexible, rapid, and in-flight reprogramming, replanning of strike and cruise missile assets, to engage a high value, emergent target, in the shortest possible time. The postulated methods of utilizing autonomous agents to manage information flow across network nodes has applicability to all digital networks.

Based upon the pioneering work of Pattie Maes at Massachusetts Institute of Technology (MIT), and previous examination of communications node management, the implementation of independent processes working on behalf of a host system to optimize the effective meaningful throughput on a communications channel is not only desirable, but necessary. The evolution of semi-intelligent software, whether called Artificial Intelligence, Intelligent Agents, or Autonomous Agents, has reached a level of sophistication allowing the insertion of meaningful articulated processes within existing, and future systems to maximize the network efficiency systematically. Recent work by Michael Cohen on Sodabots, and the evolution of user interactive TinyMUDS of the Maas-Neotek family, a virtual type personality environment, has demonstrated the ability of software to deal with dynamic and changing conditions. The exponential increase in micro-processor power has, for the first time, made available the hardware for such agent implementations as compact, self contained, embedded systems, in direct support of larger existing systems.

DATABASE ACCESS FROM THE WEB

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Determining the best method for granting World Wide Web (Web) users access to remote relational databases is difficult. Choosing the best supporting Web/database link method for implementation requires an in-depth understanding of the methods available and the relationship between the link designer's goals and the underlying issues of Performance and Functionality, Cost, Development Time and Ease, Serviceability, Flexibility and Openness, Security, State, and Session.

This thesis examined existing methods for enabling Web-client access to remote relational databases and found that most fall within the general categories of Common Gateway Interface scripts, Server Application Programming Interfaces, Web-enabled Database Management Systems exporting query results in Hypertext Markup language, and independent client-based processes such as Java applets. To determine the best database access category we compared each one to the underlying link issues and conducted a case study for the IEEE Signal Processing Society.

The results of this thesis are: (1) a taxonomy of existing Web/database linking methods, (2) a thorough listing and examination of the underlying issues as they relate to each link method, and (3) recommendation and specification of the proper link method and hardware/software support system for the case study linkage problem.

PARALLEL PROCESSING PERFORMANCE EVALUATION OF
MIXED T10/T100 ETHERNET TOPOLOGIES ON LINUX PENTIUM SYSTEMS

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The intent of this thesis is to answer the question as to whether real-time battlefield visualization, once requiring high-speed Unix workstations and specialized parallel processors, can now be now performed on relatively inexpensive off-the-shelf components.

Alternative network topologies were implemented using 10 and 100 megabit-per-second Ethernet cards under the Linux operating system on Pentium based personal computer platforms. Network throughput, processor and video performance benchmark routines were developed to assess the hardware's potential for parallel application in a distributed environment. Code was first ported to the Linux environment. Benchmark routines were then developed and tested on various machines.

Dual 200 MHz Pentium Pro processor performance exceeded the dual processor 50 MHz SUN and 40 MHz SGI Unix workstations currently used for terrain generation by a factor of 30 using a simple ray trace algorithms as a basis for comparison. The Intel Pentium Pro personal computer proved to be a capable platform for generating six to ten frame-per-second terrain simulations. However, Fast Ethernet throughput averages only 2.5 megabytes-per-second, thereby limiting the usefulness of a distributed approach designed to increase performance by dividing workload across the network.

INTRUSION DETECTION IN REAL TIME IN A MULTI-NODE,
MULTI-HOST ENVIRONMENT

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While there exist many tools and methods used to recognize intrusions into single system environments, there are few that can recognize and handle attacks in real time. This group is further reduced when adding the complexity of recognizing and handling intrusions occurring in a heterogeneous networked environment. The results of the thesis are an open architecture design for a real-time intrusion detection system to handle intrusions in a heterogeneous network and the system requirements, specifications, protocols and software module design to support an implementation of a system using this architecture. The architecture presented herein comprises a distributed system of autonomous agents that reside on the various hosts in a network. These agents communicate with each other in a coordinated effort to identify and respond to intrusions into the network by sending messages to each other detailing the identity and threat level of a potential or imminent attack. To quantify the threat level of an ongoing attack, this thesis also presents an alert level hierarchy based on the danger level and transferability of the threat to the various hosts within the network.

THE DOLPHIN DIDACTIC DATABASE SYSTEM (DODDS)

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The Naval Command, Control and Ocean Surveillance Center (NCCOSC) Research, Development, Test and Evaluation Division (NRaD) Marine Mammal Research Programs are conducted by the Marine Mammal Research & Development Branch (D35 1). Progeny is a project, under D351, that trains Atlantic Bottlenose Dolphins (Tursiops Truncatus). Progeny

was designed to explore the standardization of training, husbandry, and record-keeping techniques that contribute to preparing, operating, and maintaining dolphins for Fleet systems.

Presently, hand-written forms are filled out to record data as trainers conduct their training exercises. These forms become the source for creating reports. The current data collection process is tedious, time-consuming, and potentially unmanageable for the staff.

This thesis project provides a means to organize, gather, and maintain all the historical, current, and future data for the Progeny project. Capabilities are needed to gather the data so that timely, meaningful information, such as reports and graphs, can be made accessible to the staff.

The deliverables from this study are the development of a relational database system for organizing and storing Progeny's data, and the development of an application for entering and accessing the data within the relational database. Output reports and graphs provide information from the data.

DESIGN OF A HIGH ASSURANCE, MULTILEVEL SECURE MAIL SERVER (HAMMS)

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Computer Systems employed in the Department of Defense (DoD) for processing classified electronic mail (e-mail) generally operate at the highest classification level of the data being processed. These *system high* implementations cause two significant problems: all users must be granted unnecessarily high security clearances, and separate, incompatible workstations and networks exist for users to process classified data at different security levels. To solve these problems a System/Subsystem Specification (SSS) and a System Security Engineering (SSE) approach has been used to design a High Assurance, Multilevel Secure Mail Server (HAMMS).

This thesis presents the architecture, mailing capabilities, and required design characteristics necessary to develop a high assurance mail server. Existing high assurance and information security systems are analyzed to identify related design advantages and disadvantages for a high assurance mail server. Also included is the initialization, adaptation, and employment of a media encryption device and associated software that will be adapted to extend secure mail operations to a Commercial-Off-The-Shelf (COTS) workstation.

The result of the research is a system design that can be employed to provide a high assurance multilevel e-mail server and a reduction in the number of workstations, incompatible networks, and user clearances required in secure environments. In the future, the HAMMS design can be used as the basis for other high assurance server applications.

REAL-TIME EVENT EXECUTION MONITORING

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Currently the Computer-Aided Prototyping System software development environment provides monitoring techniques for real-time tasking execution times. However, these techniques are constrained in that there is only a provision for simple error messages to be presented upon execution failure such as that caused by a missed deadline. This approach necessitates that the software system designer haphazardly guess a task set execution time.

This thesis performed an examination of fine grain execution timing. This work was accomplished through the development of a program to perform true dynamic run time data collection of the typical task set execution exhibited within a real-time environment.

The results of this work is an accurate and efficient real-time task set execution monitoring software program which assists in overcoming the problem of task set execution run time prediction. The program itself has been embedded within the Computer-Aided Prototyping System environment and is an enhancement over the previous monitoring technique by providing the system designer with true and accurate run time execution times. The validation of the thesis work has been performed by successful design and development of time critical real-time prototype software within the Computer-Aided Prototyping System using the execution monitoring program.

A MANAGEMENT SYSTEM FOR HETEROGENEOUS NETWORKS (MSHN) SECURITY ANALYSIS

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A team of interdisciplinary experts funded by DARPA is in the process of developing a Resource Management System termed MSHN (a Management System for Heterogeneous Networks). MSHN's primary function is to accept a sequence of jobs, and intelligently determine what jobs should be executed on which machines and when. It is designed to take both machine affinity and loads into account, thus providing superior performance and Quality of Service (QoS). The current prototype of MSHN does not provide protection against the threats of inadvertent disclosure and corruption of sensitive information and resources. A rigorous security analysis of MSHN is the first step required to successfully incorporate security into the MSHN project.

The approach taken was to analyze MSHN's architecture, information flow diagrams and user interfaces and explain how fundamental security concepts may be applied to MSHN. By exercising the MSHN simulator, this work was able to expose many security weaknesses and outline conceivable methods of exploitation.

As a result of this effort, a security policy tailored to MSHN is proposed, a functional breakout process based on the principle of least privilege between common user interface capabilities and administration capabilities is provided, and finally design recommendations for the incorporation of security into MSHN are presented.

RE-ENGINEERING PORTABILITY OF THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)

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The Computer-Aided Prototyping System (CAPS) currently runs only on SPARC workstations running SunOS version 4.1.3. This limits the usefulness of CAPS, since Sun Microsystems has publicly announced that they have no interest in continuing support for SunOS version 4.x. A solution to this problem is to port CAPS to a PC platform running the Linux operating system.

Toward this end, the graphical editor portion of CAPS was ported onto a 100Mhz Pentium, with 32 MB of RAM, Linux 3.0, running Motif 2.0 on Xwindows. Modifications to both, the Makefile and the graphical editor source code were re-

quired for a successful compilation. These modifications were items such as having to compile using various compilers, providing pointers to the Motif and Xwindows Libraries needed to produce the static builds of the graphical editor, and a number of recompilations of the Linux kernel.

As a result of these efforts, the graphical editor, a functional component of CAPS, was successfully ported to this system. The software database, project control and execution support components still remain to be ported as a future development.

PROJECT SCHEDULING TOOL

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Optimally scheduling a team of developers on a large software project is an NP-complete problem. The scheduling algorithm employed by the Evolutionary Control System (ECS) portion of the Computer-Aided Prototyping System (CAPS) does near-optimal scheduling using an algorithm that runs in Order $N2$ space and time. The problem addressed by this thesis is to improve the performance of the algorithm and make it more useful for scheduling software developers. The thesis accomplished three things: (1) modified the algorithm to run in order N time and space, preserving its near-optimal behavior; (2) implemented a calendaring package that computes federal holidays for any year after 1970 and schedules tasks only on non-holiday workdays; and (3) incorporated a more realistic capability model to better match programming tasks with each developer's abilities.

VISUAL FEEDBACK FOR A STUDENT LEARNING LANGUAGE PRONUNCIATION

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The learning of language pronunciation can be a frustrating and time-consuming process. Traditional methods require feedback from another person, usually an instructor or another student, or use of a self-assessment technique such as the listen-record-and-compare technique. These techniques have flaws. Human factors such as self confidence, shyness, fatigue, hearing ability, vocal tract agility, and confidence in the instructors fairness and competence all influence how rapidly a student acquires new pronunciation skills. A new technique to replace or augment existing techniques needs to be explored.

This thesis proposes the use of a computer to provide visual feedback to both complement auditory feedback to a student and lessen the detrimental impact that these human factors have on learning pronunciation. A computer shows no bias and provides an environment that affords privacy and the ability to practice whenever the student is willing. Additionally, the use of a computer to provide visual feedback helps a student to better understand exactly what portions and in what areas the pronunciation attempt is incorrect.

This thesis identified three required areas of pronunciation feedback—phoneme, stress and intonation—and integrated them into a single interface. An object-oriented LISP implementation is presented to display the visual feedback and a design for digital speech processing is proposed to analyze the pronunciation and supply the interface with data.

JAVA BASED DATA CONNECTIVITY

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Current web database connectivity solutions lack an object—oriented architecture for Java applications. In particular, Java is object—oriented and most legacy databases are relational. This thesis proposes a design and implementation of an object—oriented java database class hierarchy for relational database interfaces.

The work reported here consists of: analysis of Java Database Connectivity specification, discussion of two—tier and three—tier architectures for database systems, mapping of relation database structure to an object model, and development of a java based framework to exercise the JDBC interfaces.

This work provides (1): an object model for the relational database; (2) Integration with a middleware application for network connectivity; (3) A Java application client to support SQL access and manipulation.

STATIC SCHEDULING OF CONDITIONAL BRANCHES IN PARALLEL PROGRAMS

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The problem of scheduling parallel program tasks on multiprocessor systems is known to be NP-complete in its general form. When non-determinism is added to the scheduling problem through loops and conditional branching, an optimal solution is even harder to obtain. The intractability of obtaining an optimal solution for the general scheduling problem has led to the introduction of a large number of scheduling heuristics. These heuristics consider many real-world factors, such as communication overhead, target machine topology, and the trade-off between exploiting the parallelism in a parallel program and the resulting scheduling overhead.

We present the *probabilistic merge heuristic*—in which a unified schedule of all possible execution instances is generated by successively scheduling tasks in order of their execution probabilities. When a conditional task is scheduled, we first attempt to merge the task with the time slot of a previously scheduled task which is a member of a different execution instance.

We have found that the merge scheduler produces schedules which are 10% faster than previous techniques. More importantly, however, we show that the probabilistic merge heuristic is significantly more scalable—being able to schedule branch and precedence graphs which exceed 50 nodes.

REALISTIC INTERFACE AND CONTROL OF A VIRTUAL SUBMARINE MODEL IN NPSNET

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The current NPSNET submarine simulator is not a viable training tool because it utilizes a control panel which runs as a separate process and includes three separate tabs, one each for the Officer of the Deck, Helm, and Weapons Officer. Besides lacking immersion qualities, most of the control icons and prototypes are not functional.

Our approach is to mount human entities to the submarine that can control and maneuver the submarine entity by interacting with various objects onboard the submarine. These human entities represent key members of the submarine control party including the Officer of the Deck, Diving Officer of the Watch, Chief of the Watch, Helmsman Planesman, and a second Planesman. The submarine model was improved by building a 3D Control Room and adding manipulable visual cues to represent an actual submarine control room.

As a result of this work, a group of human entities can operate a submarine in NPSNET, acting together as a watch team and maneuvering the submarine through the virtual environment. Realism has been improved by immersing a user into the virtual environment as a virtual human entity.

A COMPUTER SIMULATION STUDY AND COMPONENT EVALUATION FOR A QUATERNION FILTER FOR SOURCELESS TRACKING OF HUMAN LIMB SEGMENT MOTION

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Current methods of tracking the human body within virtual environments (VE) are hampered by problems due to interference which occurs from using artificially generated source signals. In recent years, the miniaturization of self-contained inertial tracking systems has made them a viable alternative. They are impervious to external interference but require filtering in order to give accurate orientation data. Filters for this purpose using Euler angles are common, but are limited by their inability to track through the vertical axis. A filter based on quaternions would not have this limitation.

This thesis presents an implementation of a quaternion filter in Lisp. The filter was tested with a computer simulated inertial tracker. Also presented is a quantitative and qualitative assessment of an existing inertial tracker, Angularis, which uses a filter based on Euler angles.

This effort resulted in an improved filter based on quaternions which allows objects to be tracked through the vertical axis making it a more desirable option for body tracking applications. The evaluation of the Angularis inertial tracker yielded generally good results when tested on a tilt-table at various rates of motion through 45 degrees of rotation. Specifically, orientation errors measured were typically less than one degree for smooth motion. However, when moved rapidly through large orientation angles, it was found that the nonlinear characteristic of the proprietary filter resulted in large steady state errors.

IMPROVING SYNTACTIC MATCHING FOR MULTI-LEVEL FILTERING

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At the center of software reuse is the search and retrieval of software components from large software libraries. Recent research has illuminated a promising approach called multi-level filtering that breaks the problem up into a series of increasingly stringent filters that move along a continuum of high-recall, low-precision syntactic techniques towards the more computationally expensive, high-precision semantic techniques.

In multi-level filtering, syntactic matching is decomposed into two phases: profile filtering and signature matching. This thesis presents improvements to the resolution of syntactic profiles where the intent is to increase precision without a loss in recall during profile filtering. Large integer representation of profiles and profile lookup tables lead to an optimal time-and-space solution to profile representation. Finally, a new approach to signature matching is proposed that provides early pruning of the search-space in an effort to cut down the time it takes to find valid signature maps.

The resulting software is mature enough for future integration with the other elements of multi-level filtering as well as inclusion in a CASE tool such as CAPS.

ON THE ROLE OF THE WORLD WIDE WEB AND
WEB TECHNOLOGY IN EDUCATIONAL COURSEWARE
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There are many types of computerized training systems available today ranging from text-based "quizzers" to interactive multimedia "edutainment." However, each system is proprietary to the platform for which the binary executable is compiled. Additionally, when the information in the training material changes, a new copy must be created, distributed and installed before it is available to the end user.

This thesis explores the use of the Java programming language as a fundamental element in the creation of interactive courseware deployable through the World Wide Web. Java is used to add interactive, executable content to Web pages in the form of simulations and complex demonstrations of educational concepts.

Complete on-line materials were developed in support of the initial offering of CS2973, a Java programming course. Following that success, a prototype interactive on-line exam system, using a Java applet and file server, was developed. This prototype foreshadows a complete virtual classroom environment supported by a Courseware Creation Interface. Both of these have the distinct advantage of being cross-platform by virtue of being created in the Java programming language, thus usable on a majority of operating systems and platforms through Java enhanced Web browsers.

ANALYSIS OF A 3-TIER DISTRIBUTED ARCHITECTURE FOR
THE SECTOR ANTI-AIR WARFARE CENTER
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The Marine Air Command and Control System (MACCS) is composed of a collection of legacy, stovepipe Automated Information Systems (AIS), each of which contain functionality which is widely duplicated throughout the MACCS. A proposed alternative architecture, the Common Air Command Control System (CAC2S), would leverage the investment currently being made in Command, Control, Communications, Computing, and Intelligence (C41) systems which provide a robust set of functional services common to a wide range of mission critical applications. A plan for migration from the MACCS architecture to the CAC2S architecture is a required component for a successful transition.

This thesis describes the messaging and database methodology, the ongoing efforts to identify common data types and processes, and a proposed three-tier distributed object architecture, which will guide the MACCS migration to the CAC2S. A Software Engineering tool, the Naval Postgraduate School Computer Aided Prototyping System (CAPS), is used to model a component of the MACCS, the Sector Anti Air Warfare Center (SAAWC), in an effort to more precisely identify the critical data type representations and data processing requirements needed to properly specify the CAC2S.

As a result of this effort, a blueprint has been created to describe the methodology and analysis required to effect the migration from the MACCS architecture to the CAC2S vision.

ARMING OUR NAVAL OFFICERS WITH TOMORROW'S TECHNOLOGY-ISSUING LAPTOP COMPUTERS TO ALL NAVAL OFFICERS

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Information superiority is the foundation for Joint Vision 2010 and the method for services to dominate the battlefield. The goal of IT21 is to rapidly implement a warfighting information network. To facilitate the engagement of information warfare, this thesis proposes that all officers be issued a laptop computer.

This thesis discusses how a computer can be as valuable as a rifle or a tank, and possibly change the way the Department of Defense fights wars. With a laptop computer, officers can have 24-hr access to critical information - turning all Naval Officers into Information Warriors! When officers transfer, they will be immediately on line at their new duty station.

This thesis uses the Technical Architecture for Information Management (TAFIM) model for strategic planning and evaluates three migration paths: a paycheck computer allowance; continuing buying desktop computers within individual command budgets; and leasing laptop computers. The alternatives are evaluated using an Information Technology Assessment Worksheet This thesis recommends that the best alternative is to lease computers for all officers and have Naval Information Systems Management Center (NISMC) be the program manager. This thesis clearly shows that after a three-year period the cost of leasing a computer is more economical than purchasing a computer.

MULTIVARIATE MOTION PLANNING OF AUTONOMOUS ROBOTS

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A problem of motion control in robot motion planning is to find a smooth transition while going from one path to another. The key concept of our theory is the steering function, used to manipulate the motion of our vehicle. The steering function determines the robot's position and orientation by controlling path curvature and speed. We also present the—neutral switching method—algorithm that provides the autonomous vehicle with the capability to determine the best leaving point which allows for a smooth transition from one path to another in a model-based polygonal world.

The above mentioned algorithm is thoroughly presented, analyzed, and programmed on a Unix workstation, and on the autonomous mobile robot Yamabico. The research data indicate that neutral switching method improved the transition results for polygon tracking, star tracking motion, and circle tracking. Moreover, neutral switching method enhances robot control and provides a more stable transition between paths than any previously known algorithm.

DECOMPOSITION RECOVERY EXTENSION TO THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS) CHANGE-MERGE TOOL

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A promising use of Computer-Aided Prototyping System (CAPS) is to support concurrent design. Key to success in this context is the ability to automatically and reliably combine and integrate the prototypes produced in concurrent efforts.

Thus, to be of practical use in this as well as most prototyping contexts, a CAPS tool must have a fast, automated, reliable prototype integration capability.

The current CAPS Change-Merge Tool is fast, automated, and uses a highly reliable formalized semantics-based change-merging method to integrate, or change-merge, prototypes which are written in Prototype System Description Language (PSDL). This method can guarantee correct merges, but it loses the prototype's design decomposition structure in the process. The post-merge prototype is fully functional, but the design decomposition structure vital to prototype understandability must be manually recovered before post-merge prototyping can continue. The delay incurred is unacceptable in a rapid prototyping context.

This thesis presents a software design and Ada implementation for a formalized algorithm which extends the current CAPS Change-Merge Tool to automatically and reliably recover a merged prototype's design decomposition structure. The algorithm is based in formal theoretical approaches to software change-merging and includes a method to automatically report and resolve structural merge conflicts. With this extension to the Change-Merge Tool, CAPS prototyping efforts, concurrent or otherwise, can continue post-merge with little or no delay.

A PRACTICAL GUIDE TO INTRANET PLANNING
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One problem an intranet planner faces is that it takes too long to research the subject. Initially, the intranet planner needs to get the "big picture"—not implementation details. This thesis will help the reader quickly grasp intranet concepts, terminology, and major issues, in order to save time in formulating an effective strategy. The thesis defines Internet, intranet, and extranet, from physical and organizational viewpoints, and introduces the issues discussed in later chapters. The control issue is shown to be the common theme in debates about centralized versus distributed computing, thin versus fat client, closed versus open access, supplier push versus user pull, and management control versus employee empowerment. There is a discussion of what Web technology does well, how to integrate it with existing technology, Java, and top-down versus bottom-up intranet development. Network architecture and firewalls are discussed, as well as, network security threats and what can be done to counter them.

HYPERMEDIA ANALYSIS AND NAVIGATION OF DOMAINS
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Hypermedia systems have been demonstrated to support authoring and reading of mostly static information. Few systems address the needs of analysts deriving information from a continuously changing base of information. Those that do, focus on the existing content and use links primarily for navigation and management. An open hypermedia architecture is proposed for a class of analysis systems where the value added by the analyst is through associating data elements. In such systems, links are the primary form of information being managed.

The architecture developed provides a framework through which hypermedia analysis systems can be generated with little or no code development. Specifically, the model is shown to apply to the domain of software engineering by mapping the analysis portions of a rapid prototyping lifecycle to a schema defined using the framework.

Through the addition of n-ary links and links to links, the architecture provides a closer mapping to the Dexter Hypertext Reference Model than current graph-based models such as the Multimedia Object Retrieval Environment (MORE). Im-

provements over MORE are also shown in the use of abstraction as a filtering mechanism and through the full involvement of links as being the primary focus of the analysis, query, and filtering functions.

QUALITY NETWORK LOAD INFORMATION IMPROVES PERFORMANCE OF ADAPTIVE APPLICATIONS

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The Joint Task Force Reference Architecture requires a Comms Server to aid client applications in adapting to changing network loads by apprising them of current and expected loads. The current Comms Server implementation estimates the network load by sending various sized packets and reporting raw performance statistics to the client. This implementation presents three problems: (1) clients interpret the statistics autonomously, (2) statistics are inaccurate due to the instantaneous collection procedure, and (3) clients also require the state of other resources to make informed decisions concerning adaptation. Development of a new Comms Server design, which solves these problems, is needed

This thesis develops a new Comms Server design and determines, through simulation, whether providing a more accurate estimate of the load could permit users of adaptive applications to obtain better performance. Simulations were run using many different situational parameters. Both the average size of the data successfully transmitted, and whether an application met its deadline, were recorded.

The results of these simulations show that clients of the existing Comms Server perform much better because they adapt, but in some cases 14% to 30% of the messages do not arrive by their deadline. However, a better design that more accurately estimates loads could deliver at least 96% of the messages on time.

AMPHIBIOUS OPERATIONS IN A VIRTUAL ENVIRONMENT

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More than 80 percent of recent, real world, naval operations have taken place in the littoral; over half have employed amphibious units. However, up till now, no simulation developed at the Naval Postgraduate School had the capability to exercise any type of naval amphibious operation. Previous simulations lacked the necessary amphibious ship and landing craft models. Second, a method for nesting mounted entities did not exist.

The approach taken was to develop a general algorithm for dynamically mounting, unmounting, and nesting entities. Secondly, amphibious ship and landing craft models were developed incorporating a simple hydrodynamic model for use with the LPD-17 and Landing Craft Air Cushion (LCAC) vehicles. Finally, real-time collision detection was implemented to ensure realistic interaction between all entities.

The result is a stand-alone, 3-D, virtual environment (VE) which simulates landing craft embarkation operations between a mother ship (LPD-17 class) and an LCAC, and allows embarked entities to walk through the 50,000 polygon LPD model in real-time (7-15 frames per second). The simulation is further enhanced by realistic wave response, based on the Pierson-Moskowitz spectrum, by all ocean borne vehicles. Lastly, the use of the high level EasyScene 3.0 API allowed the application to be written in approximately 30 percent fewer lines of code than otherwise possible.

FRONT LOADED ACCURATE REQUIREMENTS ENGINEERING (FLARE): A REQUIREMENTS ANALYSIS CONCEPT FOR THE 21st CENTURY

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This thesis focuses on ways to apply requirements engineering techniques and methods during the development and evolution of DoD software systems in an effort to reduce changes to system requirements. The major goal of this thesis is to provide a feasible course of action (COA) that reduces changes to requirements caused by the turnover of DoD decision-makers.

We demonstrate a distributed requirements engineering environment using computer aided software engineering tools linked together with electronic mail. We create this distributed requirements engineering environment using Netscape Communicator, Microsoft's Internet Explorer, Microsoft's Access97 database, Rational Corporation's Rational Rose, Matt Wright's FormMail, and Thompson Software Products' ObjectAda.

We propose a COA to reduce requirements changes caused by the turnover of decision-makers that is based on the use of specialized requirements engineering teams composed of active duty officers by the geographic and functional Commanders in Chief. These teams use the distributed requirements engineering environment described above to assist in the rapid elicitation of requirements and to increase user participation in the requirements engineering process.

USING ARTIFICIAL NEURAL NETWORKS TO IDENTIFY UNEXPLODED ORDNANCE

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The clearing of unexploded ordnance (UXO) is a deadly and time consuming process. The U.S. Government is currently spending millions of dollars to remove UXO's from bases that are closing around the world. Existing methods for detecting UXO's only inform the clearing team that a piece of metal is present, rather than the type of metal, either UXO, shrapnel, or garbage. A lot of time and money is spent digging up every piece of metal detected. This thesis presents the use of artificial neural networks to determine the type of UXO that is detected. A multi-layered feed-forward neural network using the back propagation training algorithm was developed using the language Lisp. The network was trained to recognize five pieces of ammunition. Results from the research show that four out of five pieces of ammunition from the test set were identified with an accuracy of .99 out of 1.0. The network also correctly identified that a tin can was not one of the five pieces of ammunition.

SHEPHERD ROTARY VEHICLE: MULTIVARIATE MOTION CONTROL AND PLANNING

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Millions of acres of the U.S. formerly used defense sites (FUDS) are contaminated with unexploded ordnance (UXO) as a result of past military use. The process of returning the land to the civilian sector is sensitive, intensive, and costly (e.g., millions of dollars, and the loss of human life). Hence "clearing" (i.e., site remediation, range clearance, and explosive ordnance disposal) UXO's from FUDS is a complex problem. Existing clearing methods are inaccurate, dangerous, and labor intensive. This thesis shows that through robotics technology (e.g., "Shepherd" rotary vehicle with three degrees of freedom) and the use of advanced computer technology it is possible to make clearing tasks safer, more cost-effective, and more efficient. An over arching hardware and software architecture was developed for Shepherd (including a self-contained on-board computer system). The software system was developed for timer control, motion control, user interface, and an operating kernel. The hardware and software organization, structure, and interaction provide the framework for real-time control. This research included the use of encoders, digital boards, and a counter board and required the handling of interrupts, electric motor manipulation by servomotor controllers, and communication using RS232 and VMEbus technology. The kinematics algorithms and a real-time operating kernel were implemented using the C language. "Shepherd" research has laid the foundation for the flexible, robust, and precise motion needed for UXO clearing.

A SYNTAX DIRECTED EDITOR FOR THE COMPUTER-AIDED PROTOTYPING SYSTEM

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The Computer-Aided Prototyping System (CAPS) is an integrated set of software engineering tools developed at the Naval Postgraduate School (NPS). It is designed to support rapid prototyping of real-time systems. CAPS consists of four major subcomponents; the graphics/text editor, the user interface, the software database system, and the execution support system. Reports from users of CAPS, particularly novices, indicated that the clumsy and unintuitive multi-windowed graphics/text editor present in the system hampered the use of the tool set. This thesis presents the substitution and integration of an efficient and user-friendly syntax directed editor into CAPS. The new syntax directed editor consists of a package of seven Ada95 parsers that recognize the elements of the Prototype System Description Language (PSDL) and an enhanced C\Motif based graphics editor. These modules combine the functionality of all the windows of the graphics/text editor into one window, using pop-up boxes and menus to guide the designer in providing the proper information. During integration, particular attention was paid to ensuring the proper manipulation of data was occurring between modules and the internal consistency was being maintained at the inter-language interfaces. The result is a faster, intuitive, and more efficient designer interface.

EVOLUTION OF A GRAPHICAL USER INTERFACE FOR THE RAPID PROTOTYPING OF REAL-TIME EMBEDDED SYSTEMS

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The Computer-Aided Prototyping System (CAPS) is an integrated collection of software tools that support the development of software systems utilizing the prototype paradigm. Central to CAPS is the Prototype System Description Language (PSDL). The PSDL Editor supplied in CAPS Release 1 provided a unique combination of a graphical interface for editing PSDL data flow diagrams and an attribute-grammar based text editor to enforce syntactically correct PSDL prototypes. Feedback from CAPS users highlighted on productivity impacts due to the dual user interface as well as the steep learning curve required to become proficient with the attribute-grammar based text editor.

This research initiates the development of the next generation of the CAPS PSDL Editor, focusing on the graph editor. Our approach provides a single graphical user interface with pull-down menus for editing both graphical and text information. Automatic syntax generation and validation as well as limited semantic validation is provided by a background syntax/ semantics checker. The result of this research is a working graph editor meeting all the new requirements. When integrated with a the new syntax/semantics checker, CAPS Release 2 will have a PSDL Editor with enhanced capabilities and expected productivity improvements.

AN EFFICIENT MODEL-BASED IMAGE UNDERSTANDING METHOD FOR AN AUTONOMOUS VEHICLE

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The problem discussed in this dissertation is the development of an efficient method for visual navigation of autonomous vehicles. The approach is to significantly reduce the expensive computational time of landmark detection by straight-edge features. A novel, fast straight-edge-detection method for use in autonomous vehicle navigation and other image-understanding applications is presented. Straight edges in gray-scale images are detected using a new *direction-controlled edge tracking method,* which gives precise estimate of the endpoints. To significantly reduce the number of exhaustive pixel computations, a *random-hitting method* using a pseudo-random number generator is proposed. Only if a generated pixel is significant do we start tracking the edge containing that pixel. To overcome the "noisy" gradient direction information, a robust least-squares linear fitting method is used to control the tracking process.

The results of the algorithm show how it is efficient for landmark detection, which is important for motion control of autonomous vehicles. Thus the new method is implemented as a component of the image-understanding system in the autonomous mobile robot Yamabico-11 at the Naval Postgraduate School.

An efficient world-modeling method based on the 2D model of the environment of the vehicle, including the heights of vertical edges in the environment, is presented. This modeling method is implemented with the new edge-detection method to improve the efficiency of the pose-determination algorithm (pose is a combination of the position and orientation of the camera), which is an essential task in the area of autonomous vehicle navigation.

CONCEPTUAL DESIGN OF A CYBERNETIC INFORMATION SYSTEM FOR COMMAND AND CONTROL

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This thesis argues a case for focusing command and control efforts more towards conflict deterrence vice conflict resolution and proposes a conceptual design for a command and control system to accomplish this paradigm shift. It also addresses the issue of shortening the Observe, Orient, Decide, Act (OODA) Loop of a decision-maker to enhance control while disrupting an adversary's control of a situation. Accomplishing these goals requires some method to handle the overabundance of data available for processing and analysis.

The proposed system would use advanced, but existing, information technology, incorporating cybernetic models, to enhance a decision-maker's control process. It does this by collecting, processing, and fusing all-source data for presentation to a decision-maker. Natural Language Processors categorize, filter, and fuse relevant data while advanced visualization engines display that data in a way that improves a decision-maker's ability to rapidly assimilate information, and increase knowledge and understanding.

This thesis shows that using cybernetic models, and advanced Artificial Intelligence tools, a design exists that could help increase understanding and control by improving the decision-making process and shortening the decision-maker's OODA Loop.

DESIGN OF A FINANCIAL MANAGEMENT SYSTEM FOR THE ACADEMIC DEPARTMENTS AT THE NAVAL POSTGRADUATE SCHOOL

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This thesis examines the requirements and design of a financial management system for the academic departments at the Naval Postgraduate School. Existing Systems are difficult to maintain and/or provide out-of-date information. A system is needed that is easy to use, easy to maintain, and provides current account status information so that the academic departments can make intelligent financial decisions.

We examined existing methods and tools for designing and building client/server applications. After comparing the traditional waterfall approach to the rapid prototyping approach, we elected to use rapid prototyping in order to develop the system quickly and to help the users determine their own requirements. We decided to use the *Powersoft Portfolio* tool set from Powersoft Corporation because it is scalable, transportable, affordable, and compliant with the Open Database Connectivity standard.

The result of this thesis is a prototype financial management system that users have found easy to use and maintain. The system provides summary and detail information on departmental financial accounts, to include balances and expenditures in the funding categories of faculty and support labor, equipment, travel, and contracts.

THE DESIGN OF AN INTERFACE EDITOR FOR THE
COMPUTER-AIDED PROTOTYPING SYSTEM

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This thesis focuses on the design and implementation of a new interface editor for the Computer-Aided Prototyping System (CAPS), which de-couples the user interface from the real-time prototype. Using this design, a CAPS user creates a prototype with an interface development tool and a Prototyping System Description Language (PSDL) editor. This real-time prototype executes on two processors using a client/server architecture; the user interface executes on a client, and the real-time PSDL application executes on a server. In addition, this thesis includes demonstrations, with source code, which implement the design. The demonstrations show that Java development tools can be used to create a high-quality user interface for a PSDL application. A socket connection was used to implement the client/server communication. The demonstrations were successful, but the socket programming model is too primitive for the new design. Therefore, a high-level client/server architecture, such as the Common Object Resource Broker Architecture (CORBA), is required for future development of the design.

AUTOMATIC LAYOUT TECHNIQUES FOR THE GRAPHICAL EDITOR
IN THE COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS)

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The Computer-Aided Prototyping System (CAPS) is a systems engineering tool intended to make the iterative process of software development more efficient. CAPS allows the user to investigate different designs. The simplest way to input and modify a CAPS design is through the graphical editor. When a design is modified over and over, the resultant graphical representation can become difficult to comprehend. Trying to change the graphical representation by hand can be very tedious. By adding automatic layout techniques to the graphical editor, this task is made easier for the user of the system.

Automatic layout techniques for general graphs that maximize all of the aesthetic characteristics of a graph are not possible. One characteristic may conflict with another. By giving the user multiple layout algorithms that emphasis different characteristics over others, the user may choose between different layouts for the graphical representation. When the aesthetic value of the graphical representation is increased, the cognitive process of interpreting the design is lessened.

USER INTERFACE OPTIMIZATION THROUGH BREADTH OF DISTRIBUTION ANALYSIS

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A Java tutorial was developed as a World Wide Web (WWW) site for use in capturing user behavior data. Breadth of distribution analysis was then applied to the data collected in order to characterize the usage of the user interface through the shape, connectedness, and order of traversal of each user in the sample.

The results reveal distinct user groups with different levels of user knowledge and needs in relation to the web site content. The resulting user interface analysis process produces a set of recommendations for optimizing the user interface, including adaptive interfaces for different user sub-groups and optimization of sequential rather than topical presentations.

ANALYSIS, EXPERIMENTAL EVALUATION, AND SOFTWARE UPGRADE FOR ATTITUDE ESTIMATION BY THE SHALLOW-WATER AUV NAVIGATION SYSTEM (SANS)

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The main problem addressed by this research is the lack of a small, low-cost integrated navigation system to accurately determine the position of an Autonomous Underwater Vehicle (AUV) during all phases of an underwater search or mapping mission. The approach taken utilized an evolving prototype, called the Shallow-Water AUV Navigation System (SANS), combining Global Positioning System (GPS), Inertial Measurement Unit (IMU), water speed, and magnetic heading information using Kalman, low-pass, and complementary filtering techniques. In previous work, addition of a math coprocessor improved system update rate from 7 to 18 Hz, but revealed input/output coordination weaknesses in the software. The central focus of this thesis is on testing and programming improvements which resulted in reliable integrated operations and an increased processing speed of 40 Hz. This now allows the filter to perform in real-time. A standardized tilt table evaluation and calibration procedure for the navigation filter also was developed.

The system was evaluated in dynamic tilt table experiments. Test results and qualitative error estimates using differential GPS suggest that submerged navigation with SANS for a period of several minutes will result in position estimation errors typically on the order of 10 meters rms, even in the presence of substantial ocean currents.

APPLICATION OF THE RAPID COMPUTER-AIDED PROTOTYPING SYSTEM (CAPS) IN THE DEVELOPMENT OF A SUDDEN INFANT DEATH SYNDROME (SIDS) MONITOR

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The main problem addressed by this research is to remove the need for adhesive monitors on sleeping infants who are being monitored for Sudden Infant Death Syndrome (SIDS). The approach taken was to develop the software interface prototype for the Acoustic Monitoring Pad hardware developed by the U.S. Army Research Laboratory to create the SWAM (SIDS Wireless Acoustic Monitor). The Computer-Aided Prototyping System (CAPS) Software Engineering tool of the U.S. Naval Postgraduate School was used to create the SWAM. CAPS allowed us to involve potential users and implement changes to the requirements as development progressed. Using rapid Computer-Aided Prototyping, this research demonstrates the use of acoustic sounds to monitor patients via their cardiac and respiratory sounds in a wireless fashion eliminating the use of adhesive electrodes, monitoring patients.

The results demonstrate that by using CAPS and the iterative design process, a prototype was built in less than eight months that validates the acoustic pad concept. The Unix based prototype was implemented on a laptop PC for portability, which enables other applications including mobile trauma care, in addition to infant monitoring.

IMMERSIVE ARTICULATION OF THE HUMAN
UPPER BODY IN A VIRTUAL ENVIRONMENT

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This thesis addresses the problem that virtual environments (VEs) do not possess a practical, intuitive, and comfortable interface that allows a user to control a virtual human's movements in real-time. Such a device would give the user the feeling of being immersed in the virtual world, greatly expanding the usability of today's virtual environments.

The approach was to develop an interface for the upper body, since it is through this part of users' anatomy that they interact most with their environment. Lower body motion can be more easily scripted. Implementation includes construction of a kinematic model of the upper body. The model is then manipulated in real-time with inputs from electromagnetic motion tracking sensors placed on the user.

Research resulted in an interface that is easy to use and allows its user limited interaction with a VE. The device takes approximately one sixth the time to don and calibrate as do mechanical interfaces with similar capability. It tracks thirteen degrees of freedom. Upper body position is tracked, allowing the users to move through the VE. Users can orient their upper body and control the movements of one arm. Uncorrected position data from two trackers was used to generate clavicle joint angles. Difficulty in controlling figure motion indicates that the sensors used lack sufficient registration for this purpose. Therefore, the interface software uses only orientation data for computing joint angles.

USE OF SHIP-MOUNTED ACOUSTIC DOPPLER CURRENT PROFILER DATA TO STUDY MESOSCALE OCEANIC CIRCULATION PATTERNS IN THE ARCHIPIELAGO DE COLON (GALAPAGOS ISLANDS) AND THE GULF OF THE FARALLONES

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Ship-mounted acoustic Doppler current profiler (ADCP data are used to study regional ocean patterns around the biologically rich regions of the Archipiélago de Colón (Galápagos Islands) and the Gulf of the Farallones to test the assumptions about the circulation derived primarily from hydrographic samples. West of the Galapagos, an equatorial undercurrent transport ~7 Sv was present in November 1993, which decelerated within 30 km of the archipelago, shoaled, and diverged with a strong deflection to the southwest. A method of removing tidal velocities from ADCP measurements by creating an empirical model of the tides and using it to predict and subtract the tides in described. It is shown that in the Gulf of the Farallones, a large number of observations, typically more than acquired on one cruise, are necessary to reduce tidal model error. Detided ADCP data are used to describe the circulation in the Gulf under various wind conditions. Over the continental slope, surface-to-depth poleward flow is present throughout the year. During wind relaxations, poleward flow strengthens and warmer, fresher water is transported onshore.

USSOCOM METRICS – A CASE STUDY IN MODERN
C4I NETWORK MANAGEMENT ISSUES

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Modern Department of Defense C4I systems utilize high speed commercial computer networks, composed of commercial equipment and connectivity. The United States Special Operations Command (USSOCOM's) SCAMPI (not an acronym) Network was a forerunner of this trend. Industry uses the same type of circuits but approaches the network management of these circuits from a financial interest versus the military strategic and tactical aspects considered by the service user. This thesis analyzes this representative network in the context of industry network management and metrics practices. The thesis first surveys and explains the industry practices most prevalent in this changing environment and then examines the practices in place at USSOCOM. The compilation of industry-wide network management and metrics procedures is followed by a series of solution recommendations for the SCAMPI network. These recommendations are explained in the context of current industry practices. This is followed by a series of emerging industry trends and technical developments which most likely will affect the implementation of network management and metrics tools. These developments are followed by a comprehensive industry definitions section, network bibliography, and a hypertext link guide to current military, industry and educational institutions networking solutions.

THE ASSIMILATION OF SATELLITE ALTIMETER DATA
INTO A GLOBAL EDDY RESOLVING OCEAN MODEL

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Two assimilation experiments have been conducted using the Semtner/Chervin Parallel Ocean Climate Model at 1/4° resolution to investigate the dynamical changes which occur with the application of the nudging method to incorporate sea surface height observations (with associated vertical corrections to temperature and salinity) into a global eddy resolving ocean model. The first experiment used a previous model run as the observational field to determine if the assimilation technique, nudging, produced significant changes in the simulated fields to adjust the model to the observed fields when starting at a statistically different initial condition. The twin experiment has shown that the model does respond to the inclusion of the observed fields. Both the surface fields and subsurface fields have been adjusted towards these synthetic observations. The second experiment involved the use of a combined altimetric sea surface height anomaly field from the ERS-1 and the T/P satellites. The surface height fields are extended vertically by using the Levitus 94 monthly climatological fields. This dissertation has shown that assimilation of surface height data and an associated vertical adjustment to temperature and salinity, modifies both the surface and subsurface fields. Changes can be seen in both prognostic and diagnostic quantities (such as heat content and meridional overturning) while remaining dynamically consistent with the numerics of the model itself. Comparison of the simulated fields with in situ observations of temperature and salinity show that the model has adjusted towards observation not included in the assimilation process.

MASS DISSEMINATION OF INFOSEC LECTURES VIA THE WORLD WIDE WEB

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The Naval Postgraduate School (NPS) Center for Information Systems Security (INFOSEC) Studies and Research (NPS CISR) invites experts in the field of INFOSEC to NPS to lecture on computer security. Other universities, government, and non-government organizations need similar lectures. Two problems arise: experienced security practitioners are few in number and cannot spend a considerable amount of time on the lecture circuit. Also, for many institutions a regular lecture series would be too costly. To solve these problems a method for mass distribution of the NPS security lectures must be designed.

Multi-media tools were used to capture INFOSEC lectures for cost effective mass dissemination. By using the appropriate equipment, computer technology, and software, a tool was developed which can distribute security lectures to an unlimited audience in multiple formats. The resulting product is a tutorial to give content providers a technique to take archived video tapes, digitize them, edit them, and export them. These lectures can be delivered in HTML, compact disk, and video taped formats.

An analysis of the production process yields a set of recommendations for optimizing the user interface and balancing producer and user requirements such as memory conservation, increased product quality, and accelerated remote delivery.

REMAP TMS: CAPTURING DESIGN RATIONALE
AND PROVIDING AUTOMATED REASONING

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The explosive growth of large-scale software systems results in a need for automated software engineering tools to assist in the management of software development and maintenance. Automated reasoning capture is needed to manage the dynamically changing constraints of software design. A prototype developed to manage this problem, the Knowledge Based Software Assistant (KBSA) Advanced Development Model (ADM) software design tool lacks the ability to perform automated reasoning and is unable to capture and display design rationale with different levels of detail and formality.

This thesis takes a current prototype of the REMAP Model (REpresentation and MAintenance of Process Knowledge) for representing design rationale and integrates a new truth maintenance system into a prototype called REMAP TMS. This prototype supports automated reasoning and multiple views to maintain the consistency of the rationale knowledge base. The TMS framework supports a forward chaining rule-based system that provides automated inferencing. Three levels of granularity within the Graphical User Interface (GUI) allow the capture and viewing of design rationale at increasing levels of detail.

The REMAP TMS prototype resulting from this work is now incorporated as part of the KBSA/ADM software design tool developed by the USAF and Anderson Consulting.

PROTOCOLS FOR SECURE CLIENT-SERVER APPLICATIONS IN THE JOINT MARITIME COMMAND INFORMATION SYSTEM

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The new architecture for the Joint Maritime Command Information System, referred to as JMCIS'98, seeks to provide uniform access to tactical and non-tactical information. The goal is to allow access to such information using Wide Area Network technology and Personal Computers running Windows NT in a web environment. This architecture relies on web servers to deliver executable content, such as Java applets, to clients and gateway servers to route requests to the appropriate servers and/or databases.

This architecture raises new security risks which must be addressed. Two of these risks are addressed in this thesis: executing downloaded code from a web server and transmitting sensitive information, such as passwords, to gateway servers.

We investigate three cryptographic protocols to address these risks. The first protocol treats the risk of executing downloaded code from a web server by using digital signatures. The second protocol addresses the transmission of sensitive information to a gateway server by using certificates and symmetric key cryptography. Finally, we explore an alternative approach, that of the Secure Sockets Layer, which provides mutual authentication. We discuss how the first two protocols can be implemented in Java using the Java Developer's Kit (JDK) 1.1 and the Java Cryptography Extension (JCE) 1.1.

LOW-COST DIGITAL SIGNAL PROCESSOR (DSP) BASED TORPEDO COUNTERMEASURE WITH AUTONOMOUS TARGET MOTION ANALYSIS (U)

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CLASSIFIED ABSTRACT

TECHNIQUES FOR MULTIPLE DATABASE INTEGRATION

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There are several graphic client/server application development tools which can be used to easily develop powerful relational database applications. However, they do not provide a direct means of performing queries which require relational joins across multiple database boundaries.

This thesis studies ways to access multiple databases. Specifically, it examines how a "cross-database join" can be performed. A case study of techniques used to perform joins between academic department financial management system and course management system databases was done using PowerBuilder 5.0.

Although we were able to perform joins across database boundaries, we found that PowerBuilder is not conducive to cross-database join access because no relational database engine is available to execute cross-database queries.

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